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Ph.D. Dissertation

**THE EFFECT OF RESEARCH AND
DEVELOPMENT EXPENDITURES ON
TECHNOLOGICAL CHANGE: THE CASE OF
TURKISH MANUFACTURING INDUSTRY**

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ABSTRACT

THE EFFECT OF RESEARCH AND DEVELOPMENT EXPENDITURES ON TECHNOLOGICAL CHANGE: THE CASE OF TURKISH MANUFACTURING INDUSTRY

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Economic development and growth are vital topics in economics. The most important source of economic development and growth is technological progress that is based on inventions and innovations resulting from research and experimental development (R&D) activities that are key source of long-run productivity and welfare. R&D activities are an indispensable driving force to increase the likelihood of occurrence of innovation and the growth rate of technology. In this sense, countries must behave strategically for policies on R&D, science, technology, and innovation. These topics have been considered more and more by developed and developing countries since the second half of the twentieth century.

Türkiye tends to focus on improving its industrial structure and technology as a top-priority agenda item in its industry and technology policies in recent years. Türkiye clearly recognizes that an improvement in industrial structure and technology based on invention and innovation is one of the most effective ways to solve its main economic problems such as unsatisfactory high-tech production, foreign trade deficit, and so on. Moreover, Türkiye is also aware of the importance of R&D activities, R&D expenditure, high-skilled R&D personnel, and effective policies on R&D activities more than ever. In order to develop structure of industry and technology, and to have strong R&D activities, Türkiye must implement key policies on R&D, science, technology, innovation, and industry. However, studies on the impact of R&D activities on the likelihood of occurrence of product and process innovation in Turkish manufacturing industry using micro data sets are still insufficient. There is a need to analyze Turkish manufacturing industry deeply regarding subsectors from different perspectives. To fill this gap, this study aims to analyze firms that are engaged in R&D activities in Turkish manufacturing industry are analyzed to reveal the effects of R&D

on the likelihood of occurrence of product and process innovation. The study also presents policy recommendations to support determination process of R&D, S&T, and innovation policies in Türkiye.

To accomplish these objectives, panel data estimation methods are used. A panel data set was generated by merging four different microdata sets provided by TURKSTAT, which is classified by NACE Rev. 2. This panel data set covers the years between 2009 and 2016 because changes in innovation questionnaire and limited data from TURKSTAT. Probit model is used to estimate the effects of R&D expenditure, R&D intensity (as an indicator of R&D investment), R&D personnel ratio (as an indicator of know-how), turnover, Herfindahl-Hirschman index, and industrial production index by manufacturing industry on the likelihood of occurrence of product and process innovation. Moreover, Total R&D expenditure and total R&D intensity are separated into four breakdowns such as internal, external, external-domestic, and external-foreign. This investigation comprises five different perspectives of analyzing Turkish manufacturing industry such as: as a whole (by section C), by industries (division), by technology intensity classification, by education intensity classification, and by firm size classification.

Key findings of the research showed that the effects of R&D expenditure and R&D intensity on the likelihood of occurrence of product and process innovation vary by their breakdowns, by five different perspectives, and by innovation types.

According to results of the analysis on all manufacturing industry (as a whole), all R&D expenditures except *external-foreign R&D expenditure* have positive effect on the likelihood of occurrence of product innovation while all R&D expenditures except *external-domestic R&D expenditure* have positive effect on the likelihood of occurrence of process innovation. Moreover, all R&D intensities except *internal R&D intensity* have positive effect on the likelihood of occurrence of product innovation while all external R&D intensities have positive effect on the likelihood of occurrence of process innovation. Additionally, the impact of *total R&D expenditure* on the likelihood of occurrence of process innovation is greater than its impact on the likelihood of occurrence of product innovation. The impacts of *internal* and *external*

R&D expenditures on the likelihood of occurrence of product innovation are greater than its impact on the likelihood of occurrence of process innovation. The impact of *external, external-domestic, and external-foreign R&D intensity* on the likelihood of occurrence of process innovation is greater than its impact on the likelihood of occurrence of product innovation. According to results of the analysis on Turkish manufacturing industry from other perspectives such as by industries (division), by technology intensity classification, by education intensity classification, and by firm size classification, it is seen that the effects of R&D expenditure and R&D intensity on the likelihood of occurrence of product and process innovation vary by their breakdowns and by innovation types. Results of these analyses can be found in this study in detail.

According to the results of the study, policies are recommended for Turkish manufacturing industry such as: (i) R&D expenditure and R&D intensity must be increased to support product and process innovation by regarding the sectoral differences, classifications, R&D expenditure types, and innovation types; (ii) the number of R&D personnel must be increased to enhance adaptability of firm/sector to technology and to increase the likelihood of occurrence of product and process innovation; (iii) efficient education system is needed for a sustainable innovative culture in the country and to grow more researchers, scientists, educated workers and managers; (iv) technological infrastructures and technology level of institutions must be updated consistently for acceleration of R&D activities.

Keywords: Product Innovation, Process Innovation, Turkish Manufacturing Industry, R&D Expenditure, R&D Policy.

ÖZ

ARAŞTIRMA VE GELİŞTİRME HARCAMALARININ TEKNOLOJİK DEĞİŞİM ÜZERİNDEKİ ETKİSİ: TÜRK İMALAT SANAYİ ÖRNEĞİ

ATAKAN AKINCI

İktisadi kalkınma ve büyüme iktisatta hayati konulardır. İktisadi kalkınma ve büyümenin en önemli kaynağı, refahın ve uzun dönemli verimliliğin temel kaynağı olan araştırma ve deneysel geliştirme (AR-GE) faaliyetleri sonucunda ortaya çıkan buluşlara ve inovasyonlara dayalı teknolojik ilerlemedir. AR-GE faaliyetleri, inovasyonun gerçekleşme olasılığını ve teknolojinin büyüme hızını arttırmak için vazgeçilmez bir itici güçtür. Bu anlamda, ülkeler AR-GE, bilim, teknoloji ve inovasyon politikaları için stratejik davranmalıdır. Yirminci yüzyılın ikinci yarısından itibaren gelişmiş ve gelişmekte olan ülkeler tarafından bu konular giderek daha fazla ele alınmaktadır.

Türkiye son yıllarda sanayi ve teknoloji politikalarında öncelikli gündem maddesi olarak sanayisinin yapısını ve teknolojisini geliştirmeye odaklanma eğilimindedir. Türkiye, yetersiz yüksek teknolojili üretim, dış ticaret açığı vb. ana ekonomik sorunların çözümü için buluşlara ve inovasyonlara dayalı bir sanayi yapısının ve teknolojinin en etkili yollardan biri olduğunun açıkça farkındadır. Ayrıca, Türkiye, AR-GE faaliyetlerinin, AR-GE harcamasının, yüksek vasıflı AR-GE personelinin ve AR-GE faaliyeti üzerine etkin politikaların öneminin her zamankinden daha fazla farkındadır. Sanayi ve teknoloji yapısını geliştirmek ve güçlü AR-GE faaliyetlerine sahip olabilmek için, Türkiye temel ARGE, bilim, teknoloji, inovasyon ve sanayi politikalarını uygulamalıdır. Ancak, mikro veriler kullanılarak Türkiye'deki AR-GE faaliyetlerinin ürün ve süreç inovasyonunun gerçekleşme olasılığı üzerindeki etkisi üzerine yapılmış çalışmalar hâlâ yetersizdir. Türk imalat sanayinin alt sektörler bazında ve farklı açılardan derinlemesine analiz edilmesine ihtiyaç vardır. Bu eksikliği doldurmak için bu çalışmada, AR-GE'nin ürün ve süreç inovasyonlarının gerçekleşme olasılığı üzerindeki etkisini ortaya çıkarmak için Türk imalat sanayinde AR-GE faaliyetlerinde bulunan firmaların analizi amaçlanmıştır. Bu çalışma, ayrıca

Türkiye’de AR-GE, bilim ve teknoloji ve inovasyon politikalarının belirlenme sürecini destekleyecek politika önerileri sunmaktadır.

Bu amaçları gerçekleştirmek için, panel veri tahmin yöntemleri kullanılmıştır. NACE Rev. 2’ye göre sınıflandırılmış bir panel veri seti TURKSTAT tarafından yapılan anketlerden derlenen dört farklı mikro veri seti birleştirilerek oluşturulmuştur. Bu panel veri seti, inovasyon anketindeki değişiklikler ve TÜİK verilerinin sınırlı olması nedeniyle 2009-2016 yıllarını kapsamaktadır. AR-GE harcamasının, AR-GE yoğunluğunun (AR-GE yatırımı göstergesi olarak), AR-GE personel oranının (know-how göstergesi olarak), cironun, Herfindahl-Hirschman endeksinin ve sanayilere göre sanayi üretim endeksinin ürün ve süreç inovasyonunun gerçekleşme olasılığı üzerindeki etkilerini tahmin etmek için probit model kullanılmıştır. Ayrıca, içsel, dışsal, dışsal-yurt içi ve dışsal yurt dışı olarak toplam AR-GE harcaması ve toplam AR-GE yoğunluğu dört alt kırılıma ayrılmıştır. Bu araştırma, Türk imalat sanayini analiz eden beş farklı bakış açısını içermektedir: bir bütün olarak (bölüm C), sanayilere göre (alt bölüm), teknoloji yoğunluğu sınıflandırması, eğitim yoğunluğu sınıflandırması ve firma büyüklüğü sınıflandırması.

Araştırmanın temel bulguları, AR-GE harcamasının ve AR-GE yoğunluğunun ürün ve süreç inovasyonunun gerçekleşme olasılığı üzerindeki etkilerinin alt kırılımlara, beş farklı bakış açısına ve inovasyon türlerine göre değiştiğini göstermektedir.

Türk imalat sanayi üzerinde yapılan analiz sonuçlarına göre (bütün olarak), dışsal-yurt dışı AR-GE harcaması hariç bütün AR-GE harcaması türleri ürün inovasyonunun gerçekleşme olasılığı üzerinde pozitif bir etkiye sahipken, dışsal-yurtiçi AR-GE harcaması hariç bütün AR-GE harcaması türleri süreç inovasyonunun gerçekleşme olasılığı üzerinde pozitif etkiye sahiptir. Ayrıca, içsel AR-GE yoğunluğu hariç bütün AR-GE yoğunluğu türleri ürün inovasyonunun gerçekleşme olasılığı üzerinde pozitif bir etkiye sahipken, AR-GE yoğunluğu türlerinin hepsi süreç inovasyonunun gerçekleşme olasılığı üzerinde pozitif etkiye sahiptir. Bunlara ek olarak, toplam AR-GE harcamasının süreç inovasyonunun gerçekleşme olasılığı üzerindeki etkisi, ürün

inovasyonunun gerçekleşme olasılığı üzerindeki etkisinden daha büyüktür. İçsel ve dışsal AR-GE harcamalarının ürün inovasyonunun gerçekleşme olasılığı üzerindeki etkisi, süreç inovasyonunun gerçekleşme olasılığı üzerindeki etkisinden daha büyüktür. Bütün dışsal AR-GE yoğunluğu türlerinin süreç inovasyonunun gerçekleşme olasılığı üzerindeki etkisi, ürün inovasyonunun gerçekleşme olasılığı üzerindeki etkisinden daha büyüktür. Benzer şekilde, Teknoloji yoğunluğu sınıflandırması, eğitim yoğunluğu sınıflandırması, firma büyüklüğü sınıflandırması ve imalat sanayileri (alt bölüm) gibi diğer bakış açılarıyla Türk imalat sanayinin analizinin sonuçlarına göre, AR-GE harcamasının ve AR-GE yoğunluğunun ürün ve süreç inovasyonunun gerçekleşme olasılığı üzerindeki etkileri bunların alt kırılımlarına göre ve inovasyon türlerine göre değiştiği görülmektedir. Bu analizlerin sonuçları, bu çalışmada ayrıntılı olarak bulunmaktadır.

Bu çalışmanın sonuçlarına göre, Türk imalat sanayi için bazı politikalar önerilmektedir: (i) ürün ve süreç inovasyonunu desteklemek için sektörel farklılıklar, sınıflamalar, AR-GE harcaması türleri ve inovasyon türleri dikkate alınarak AR-GE harcaması ve AR-GE yoğunluğu arttırılmalıdır; (ii) firma/sektörün teknolojiye uyum yeteneğini geliştirmek ve ürün ve süreç inovasyonunun gerçekleşme olasılığını arttırmak için AR-GE personeli sayısı arttırılmalıdır; (iii) ülkede daha fazla araştırmacı, bilim insanı, eğitilmiş işçi ve yönetici yetiştirmek ve sürdürülebilir bir inovasyon kültürü için etkin bir eğitim sistemine ihtiyaç vardır; (iv) AR-GE faaliyetlerinin hızlanması için kurumların teknolojik altyapılarının ve teknoloji seviyelerinin sürekli olarak güncellenmesi gerekmektedir.

Anahtar Kelimeler: Ürün İnovasyonu, Süreç İnovasyonu, Türk İmalat Sanayi, AR-GE Harcaması, AR-GE Politikası.

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LIST OF ABBREVIATIONS

AISS	: Annual Industry and Service Statistics
BRF	: Annual Business Registers Framework Micro Data Set
CDF	: Cumulative Standard Normal Distribution Function
CIS	: Community Innovation Survey Micro Data Set
CR	: Concentration Ratio
DRC	: Data Research Center
EII	: Education Intensity Index
EUROSTAT	: Statistical Office of the European Union
EU	: European Union
FORD-2015	: Fields of Science and Technology
FNFC	: Financial and Non-Financial Corporations
FS	: Firm Size
FTS	: Foreign Trade Statistics Micro Data Set.
GDP	: Gross Domestic Product
GERD	: Gross Expenditure on Research and Development
GG	: General Government
HE	: Higher Education
HHI	: Herfindahl-Hirschman Index
ICT	: Information and Communication Technology
ID	: Firms' Identity No given by TURKSTAT
IMF	: International Monetary Fund
IS	: Innovation Survey Micro Data Set
ISCED-2011	: International Standard Classification of Education
ISCO-08	: International Standard Classification of Occupations
ITSP	: Industry and Technology Strategic Plan
NACE	: Statistical Classification of Economic Activities in the European Community (Nomenclature statistique des activités économiques dans la Communauté européenne)
N.E.C.	: not elsewhere classified
OECD	: Organisation for Economic Co-operation and Development
OECD NESTI	: OECD Working Party of National Experts on Science and Technology Indicators (NESTI)
PRODCOM	: Annual Industrial Products Statistics Micro Data Set
R&D	: Research and Experimental Development
RDAS	: Research and Development Activities Surveys in Business Enterprise Sector Micro Data Set
SIS	: State Institute of Statistics in Türkiye (now TURKSTAT)

SME	: Small and Medium-Sized Enterprise
SOE	: State-Owned Enterprise
SPO	: State Planning Organization
SR	: Classification of Statistical Regions
S&T	: Science and Technology
TDZ	: Technology Development Zone
THE UK	: The United Kingdom
THE US	: The United States
TI	: Technology Intensity
TURKSTAT	: Turkish Statistical Institute
TÜBİTAK	: the Scientific and Technological Council of Türkiye
TÜRKPATENT	: Turkish Patent and Trademark Office
VIF	: Variance Inflation Factors
WB	: World Bank
WWI	: First World War
WWII	: Second World War
5YDP	: Five-Year Development Plan

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INTRODUCTION

Since ancient times, there has been a constant stream of technological innovations and advancements. Human beings have invented and innovated many tools to meet needs and wants, to gain utility and to generate profit such as bifacial tools, axes, dugouts, screw, wheels, weaving looms, steam engine, new materials (metallurgical or not), telegraph, tires, container, radio, car, airplane, television, transistor, computer, and so on. These kinds of technological developments and research and development (R&D) activities have increased in the last two centuries (especially in the 20th century) increasingly after the Industrial Revolution that human and animal muscle power have been supplanted by mechanical power.

In the early 1900s, transportation and communication have been developed substantially. The mid-1900s, some developments such as television, computers, and nuclear power, space related technologies have changed human life irrevocably. In the late 1900s, diffusion and adoption of new technologies such as personal computer, mobile technologies and internet have changed the flow of daily life socially, economically, and politically. In the early 2000s, especially smart technologies and artificial intelligence have accelerated the changes. Together with new innovations the world transformed into a kind of village and technology became a part of life.

Throughout the twentieth century, there was a steady increase in R&D activities, particularly driven by military objectives. This trend was further intensified during the World Wars, resulting in a general rise in R&D spending. However, during the period between the two World Wars, because of the Great Depression, R&D expenditure level was relatively less than ensuing years. After the Second World War (WWII), countries have increased their R&D expenditure dramatically to innovate new technologies and to do research in many fields such as ICT, transportation, biotechnology, aerospace, defense, electronics etc. for their competitiveness and economic growth and development. According to Türkcan (2013), the internalization of technology is essential for the development of any country.

Economic development and economic growth are vital topics in economics. Countries strive to achieve robust capital accumulation, enhance labor productivity, and foster significant technological advancements, all while maintaining a sustainable framework, in order to foster development and growth. The most important source of economic development and growth is technological progress thanks to inventions and innovations resulting from research and experimental development (R&D) activities. Therefore, a country may produce its own technology that causes an increase in productivity and decrease in production costs. In this sense, countries must behave strategically for policies on R&D, science, technology, and innovation. These topics have been considered more and more by developed and developing countries since the second half of the twentieth century.

Organization for Economic Co-operation and Development (OECD) Working Party of National Experts on Science and Technology Indicators (NESTI) agreed on Frascati Manual in 1963 and Oslo Manual in 1992. Frascati Manual 1963 and Oslo Manual 1992 have provided a methodology for collecting and using R&D statistics, and a guideline for collecting, reporting, and using data on innovations, respectively (OECD, 1963, 1992).

Türkiye¹ has introduced development plans in the 1930s, several five-year development plans (5YDP) since the 1960s, and many industry and technology strategic plans (ITSP) based on 5YDP. Türkiye tends to focus on improving its industrial structure and technology as a top-priority agenda item in its industry and technology policies in recent years, since Türkiye clearly recognizes that an improvement in industrial structure and technology based on invention and innovation is one of the most effective ways to solve its main economic problems such as unsatisfactory high-tech production, foreign trade deficit, and so on. Türkiye is also aware of the importance of R&D activities, R&D expenditure, high-skilled R&D personnel, and effective policies on R&D activities more than ever. To accomplish those aims, Türkiye must implement key policies to support and to accelerate its R&D

¹ I used the term “Türkiye” instead of “Turkey” because of circular no. 2021/24 on use of ‘Türkiye’ as a brand instead of ‘Turkey’, ‘Turkei’, ‘Turquie’, and other similar phrases in all types of activities and correspondence was promulgated in the Official Gazette no. 31679 on 4 December 2021.

activities. For example, Türkiye published the Turkish Science and Technology Policy 1993-2003 document in 1993 and introduced the Law on Technology Development Zones (TDZ) in 2001, and the Law on Supporting Research, Development and Design Activities in 2008.

Türkiye is a country that aims to grow and to develop by providing technological progress. R&D activities are supported with several programs and laws to achieve targets such as sustainable economic growth and development. The share of R&D expenditure in GDP has increased since the early 2000s and is around 1.03% in 2018 in Türkiye (in 2016 after revision, see Figure 3). This share is less than the share of OECD-total (2.4%) and European Union (2.0%) (OECD, 2022). For OECD countries, in 2022, the highest share is approximately 5.4% in Israel, 4.8% in Korea, between 3% and 3.5% in Sweden, United States, Belgium, Japan, Austria, and Germany, which are shown in Appendix 19. The share in Chinese Taipei, one of the non-OECD economy, is approximately 3.6%, which is also shown in Appendix 19.

Although Türkiye has a low ratio (R&D expenditure/GDP), it is a remarkable country in terms of high growth rates in recent years. However, in last two centuries, the growth rate of per capita income² is as much as average of the developing countries' (more than regions' such as the South America, Africa, and the Middle East but less than Italy, Spain, Japan, and the South Korea) (Pamuk, 2016). The growth is mostly based on an increase in capital stock instead of R&D activities. To increase and to sustain high growth rates, Türkiye must increase the share of total factor productivity in economic growth and the growth rate of technology. The best method to increase and to sustain the growth rate of technology requires more R&D activities. R&D activities are a key source of long-run productivity and welfare through innovation (Jones and Williams, 2000).

Türkiye must produce its own technology by performing R&D activities. R&D activities is a source of knowledge and scientific knowledge that is the source of technological innovation (Kepenek, 2020). However, there are some problems about

² For Developing Countries: 0.3% for 1820-1950, 3.1% for 1950-2010, 1.2% for 1820-2010. For Türkiye: 0.6%, 3.2%, and 1.4%, respectively. Pamuk (2016) provided these indicators from the source of Maddison (2007).

R&D activities and economy in Türkiye, which are highlighted by Öztürk (2019), such as:

- i) Government subventions have significant effect on organizational and marketing innovations (for short-term profit) by comparison product innovation that generates value-added for an economy.
- ii) Innovations generally focus on organizational and marketing innovations instead of product and process innovation.
- iii) The structure of Turkish manufacturing industry is based on low-tech sector that shows low productivity and organizational innovations in these sectors is not efficient for the economy.
- iv) The structure of Turkish economy is based on service sector that has lower productivity than manufacturing.

In a nutshell, Türkiye must attach great importance to R&D activities and innovations (e.g., product and process innovation) in manufacturing industry to boost its economy more than ever. Because more R&D activities provide a great environment by producing knowledge, to increase the likelihood of occurrence of product and process innovation that are the sources of knowledge accumulation (Aghion and Howitt, 1992).

To develop efficient and strategic policies, factors that affect R&D activities in Türkiye must be investigated further regarding the differences among industries (Taymaz and Saatçi, 1997). In the shadow of these developments, Turkish Statistical Institute (TURKSTAT) has conducted Community Innovation Surveys (CIS) since 2004 in Türkiye, which is based on the Frascati Manual and the Oslo Manual (TURKSTAT, 2020).

Based on the share of R&D expenditure in GDP over time in Türkiye and other country experiences, which are shown in Appendix 19, and based on the problems of Turkish economy in terms of R&D activities, which are summarized by Öztürk (2019), I mainly questioned R&D activities and R&D indicators thoroughly in my mind such as:

- What is the effect of R&D expenditure and R&D intensity on product and process innovation in Turkish manufacturing industry?
- Do R&D expenditure and R&D intensity increase the likelihood of occurrence of product and process innovation in Turkish manufacturing industry?.

In addition to these reasons, there are also some gaps in theory to be contributed in terms of R&D and innovation. Theoretical reasons are mainly based on endogenous growth model and R&D literature. Romer (1987, 1990), Aghion and Howitt (1992), and Grossman and Helpman (1991a, 1991b, 1991c) emphasized many issues such as technological progress based on R&D activity, reward after R&D activity as a monopoly power, and nonoptimal amount of R&D activity and rate of growth. Additionally, this endogenous model is mainly based on some explanations such as: R&D expenditure is significant factor to encourage R&D activities of firms that cause technological progress through innovation (Romer, 1990; Aghion and Howitt, 1992). R&D expenditure and R&D intensity variables are prominent variables and one or both is used several times (Hamberg, 1964; Mansfield, 1964; Markham, 1965; Subrahmanian, 1971; Soete, 1979; Mansfield, 1981; Acs and Audretsch, 1988a, 1988b). A positive relationship between R&D expenditure and innovative output (Acs and Audretsch, 1988a, 1988b) and correlation between R&D intensity and firm's inventive output (Mansfield, 1964) were found. So, in this dissertation, these relationships between R&D expenditure and innovative output (product or process innovation), and between R&D intensity and innovative output (product or process innovation) are going to be searched for Turkish manufacturing industry. However, Mansfield (1983) showed that there is no relationship between R&D intensity (R&D expenditure/sales) and innovative outputs such as product and process innovation. So, in this dissertation, contradictory results between innovation (product and process) and R&D intensity is also going to be searched for Turkish manufacturing industry.

Most of studies on other countries also affected the focus of this dissertation such as studies *in America* [Hamberg (1964)], *in India* [Subrahmanian (1971)], *in Italia* [Santarelli and Sterlacchini (1990)], *in Netherlands* [Audretsch, Menkveld, and Thurik (1996)], *in France* [Crepon, Duguet, and Mairessec (1998)], *in Spain*

[Martinez-Ros (1999)], in *Portugal* [Carvalho, Costa, and Caiado (2013)], in *Czechia* [Zemplinerova and Hromadkova (2012)], in *Norway* [Clausen, Korneliusen, and Madsen (2013)], in *South Korea* [Kim (2000), Song and Oh (2015)], in *United Kingdom* [Albaladejo and Romijn (2000)], in *Canada* [Cumming and Macintosh (2000)], in *Germany* [Fritsch and Meschede (2001)], in *Malaysia* [Lee (2004)], in *Australia* [Bhattacharya and Bloch (2004)], in *European Union* [Avermaete, Viaene, and Morgan, et.al. (2004)], in *Finland* [Leiponen (2005)], in *Israel* [Shefer and Frenkel (2005)], in *Croatia* [Radas and Božić (2009)], and in *Nigeria* [Adeyeye et al. (2016)], which are referred in Chapter I in detail. They are focused on R&D and innovation by high-tech classification, firm size, energy intensity classification, and by separating innovation into product and process. The importance of highly skilled labor and education is also emphasized in technological progress. Moreover, they generally investigated the effect of R&D on innovation. It is clearly seen that R&D activities, R&D intensity, R&D personnel, technological resources of firm, and tangible investments lead to an increase in the likelihood of occurrence of product innovation. In other words, R&D activities and expenditures increase the likelihood of occurrence of innovation. In this dissertation, it is hypothesized shortly that R&D expenditure and R&D intensity increase the likelihood of occurrence of product and process innovation in Turkish manufacturing industry. Moreover, it is seen that there are differences between the effects on product and on process innovation. In this dissertation, these differences are searched for Turkish manufacturing industry.

Nelson and Winter (1977) emphasized the importance of micro-level and industry-level studies of technical change to get more productive results. Taymaz and Saatçi (1997) underlined that sectoral differences must be taken account in studies. Subodh (2002) showed the importance of inter-industry differences and emphasized that testing the hypothesis in different industries separately is the best method to reveal the inter-industry differences. Töngür and Taymaz (2019) emphasized the importance of determining and designing sectoral policies by firm size instead of general policies. Bakır et al. (2019) also emphasized that determining “specific” industry and technology policies to prevent decrease in value-added and increase in import dependency. In this sense, sectoral analyses will help to make different policies for

each sector in Turkish manufacturing industries. In the light of these emphases, this dissertation aims to support policy makers in determining R&D and technology policies and designing sector level programs and policies that will be conducted in the future in Türkiye.

In this sense, the effect of R&D expenditure and R&D intensity on the likelihood of occurrence of product and process innovation in Turkish manufacturing industry are analyzed from five different perspectives such as: as a whole (by section C); by sectors (by division); technology intensity classification; education intensity classification; and firm size classification. Because, in Türkiye, studies on R&D activities and innovation mostly focused on growth and productivity, mostly related to macroeconomics perspectives. Although there are studies on Turkish manufacturing industry, they are shallowly and mostly focused on the manufacturing industry as a whole (Pamukçu and Boer De, 2000; Uzun, 2001; Özdemir-Güngör & Gözlü , 2012; Attar, 2017; Burmaoğlu ve Şeşen, 2017; Doğan, 2017; Öztürk, 2018-2019).

According to studies about Türkiye in terms of the research on the effect of R&D expenditure and R&D intensity on the likelihood of occurrence of product and process innovation in Turkish manufacturing industry, there are some gaps in studies on Türkiye such as:

- i. Ignoring differences among the industries, in other words subsectors (divisions) are not analyzed clearly at the same time. Industry is generally analyzed as a whole (by section C) in literature.
- ii. Lack of different perspectives (as a whole, classifications of NACE Rev. 2 2-digit, TI, EII, and FS).
- iii. R&D expenditure and R&D intensity are not separated into its breakdowns to understand the effect of each of them. For example, *total R&D expenditure*, *internal R&D expenditure*, *external R&D expenditure*, *external-domestic R&D expenditure*, and *external-foreign R&D expenditure*.
- iv. Innovations are not separated into their types such as product and process.

In addition, in the light of micro data sets that were provided by TURKSTAT and these gaps in the literature, some questions were not be discussed for Turkish manufacturing industry such as:

- Which type of R&D expenditure and R&D intensity have more effect on product and process innovation in Turkish manufacturing industry?
- What is the effect of R&D expenditure and R&D intensity on product and process innovation in Turkish manufacturing industry that is clustered and classified by NACE Rev. 2 2-digit, EII, TI, and FS?

As far as it is known, there are no comprehensive and detailed studies on Türkiye like explained above from the perspective of product and process innovation. I aimed to contribute to the literature by investigating Turkish manufacturing industry in details from different perspectives as explained above, and contribute to R&D, innovation, and technology policies development process in Türkiye.

In order to support determination process of R&D policies, to solve some problems about R&D activities and economy in Türkiye, which are highlighted by Öztürk (2019), to fill the gaps in the literature that mentioned above, and to investigate research questions that mentioned above, I focused on analyzing Turkish manufacturing firms for the years between 2009 and 2016 (because of data availability for this period) to reveal the relationship between innovation (product and process innovation) and its determinants, and the effect of R&D expenditure and R&D intensity on the likelihood of product and process innovation. This investigation comprises five different perspectives of analyzing Turkish manufacturing industry (i) as a whole (by section C), (ii) by industries (division), (iii) by technology intensity, (iv) by education intensity, and (v) by firm size, which are explained in detail.

- i) The first perspective aims to analyze Turkish manufacturing industry as a whole (by section C). This analysis provides general results for the industry but no detailed results for divisions of the industry. These results help to produce policies on R&D activities for the whole industry but do not help for the divisions such as manufacture of food products, beverages, textiles, basic metals, electrical equipment, computer, electronic and optical

products, and so on. The policies on the whole industry provide a general framework and may not be a perfect solution for each industry separately because each industry has its own characteristics and structure in the economy. It is necessary to analyze Turkish manufacturing industry by division to support development of policies on specific industry.

- ii) The second perspective focused on the analysis of the divisions of the manufacturing industry by NACE Rev. 2 2-digit to help for the development of policies on R&D activities by discussing the differences between industries. This analysis will help find answers to main questions in terms of the divisions of Turkish manufacturing industry to reveal differences among sectors.
- iii) The third one focused on the classification of the industry by technology intensity (TI) such as high tech (HT), medium-high tech (MHT), medium-low tech (MLT), and low tech (LT). It is aimed to reveal differences between technology intensity classifications. It is well known that each technology intensity class of the industry needs different policy solutions for their characteristic and structural problems. This analysis will help to find answers to main questions by technology intensity classification.
- iv) The fourth one is about the clustering of the industry by education intensity such as high education, medium-high education, medium-low education, and low education. Cluster analysis is used to achieve the clustering of Turkish manufacturing industry by education intensity index that is calculated with respect to the data about the education level of R&D personnel who work in the manufacturing industry firms engaged in R&D activities. This analysis will help to find answers to main questions by technology intensity classification. The analysis is significant to understand the importance of educated and skilled labor in terms of innovative performance of manufacturing firms because understanding new technology and using it are not easy for firms and labor force. The adoption and adaptation abilities of firms for new technology may affect the

performance of production and innovativeness of firm negatively because new production techniques or technologies mostly are not understood completely because of low educated and unskilled workers. The lack of these kinds of abilities in the firm brings insufficient innovative performance and in turn decreases the likelihood of introducing product and process innovation. For instance, when new technology is developed or transferred to the firm, the labor force who may not understand how it works cannot use new technology effectively therefore research capacity and production capacity cannot reach its potential capacity in the firm in turn in the industry. To use new technology efficiently and to take more advantage of innovations, firms must improve their adoption and adaptation abilities by changing their organization of production and by investing in their infrastructure and in education of workers.

- v) The last perspective is based on firm size such as small, medium, and large. This analysis will help to find answers to main questions by firm size classification, to reveal differences among small, medium, and large firms.

To achieve the analyses of Turkish manufacturing industry from five perspectives, following research objectives and steps would facilitate the achievement of the dissertation outcomes:

- i) Generating a panel data to analyze product and process innovation in Turkish manufacturing industry for the period between 2009 and 2016.
- ii) Identifying factors that affect innovativeness of Turkish manufacturing firms in terms of product and process innovation.
- iii) Calculating education intensity index (EII) to ease the clustering of Turkish manufacturing industry by education intensity.
- iv) Classifying Turkish manufacturing industry by technology intensity, education intensity, and firm size.
- v) Separating R&D expenditure and R&D intensity into their breakdowns such as total, internal, external, external-domestic, and external-foreign.

vi) Analyzing the impacts of R&D expenditure and R&D intensity on product and process innovation in Turkish manufacturing industry from five different perspectives.

vii) Providing efficient policies resulting from all analyses.

The dissertation provides a few originalities such as:

- i) Well-known variable, R&D expenditure, is used to analyze Turkish manufacturing industry by separating into its breakdowns such as (*total R&D expenditure, internal R&D expenditure, external R&D expenditure, external-domestic R&D expenditure, and external-foreign R&D expenditure*). Moreover, R&D intensity is also used to analyze Turkish manufacturing industry by separating into its breakdowns such as (*total R&D intensity, internal R&D intensity, external R&D intensity, external-domestic R&D intensity, and external-foreign R&D intensity*). This is the first originality of the dissertation.
- ii) Education level of R&D personnel employed in R&D activities of firms in Turkish manufacturing industry is considered to analyze the impact of R&D expenditure and R&D intensity on the likelihood of occurrence of product and process innovation. With the help of this data, the education intensity index (EII) is calculated to cluster the industry by education intensity. I clustered the industry by using education intensity index (EII) such as industries with High Education Intensity (HEI), Medium-High Education Intensity (MHEI), Medium-Low Education Intensity (MLEI), and Low Education Intensity (LEI). This is the second originality of the dissertation.
- iii) The impacts of R&D expenditure and R&D intensity on the likelihood of occurrence of product and process innovation in Turkish manufacturing industry is analyzed by separating each industry by NACE Rev. 2 2-digit (by division). This is the third originality of the dissertation.

- iv) Technology intensity (TI) classification is considered to analyze the impact of R&D expenditure and R&D intensity on the likelihood of occurrence of product and process innovation. The industry is separated into subgroups in terms of TI classification such as High Technology (HT), Medium-High Technology (MHT), Medium-Low Technology (MLT), and Low Technology (LT). This is the fourth originality of the dissertation.
- v) Firm size (FS) is considered to analyze the impact of R&D expenditure and R&D intensity on product and process innovation in Turkish manufacturing industry. The industry is analyzed from the perspective of firm size such as small, medium, and large. This is the fifth originality of the dissertation.

In a nutshell, this dissertation aims to analyze Turkish manufacturing firms that engaged in R&D between 2009 and 2016 by investigating relationships between the likelihood of occurrence of product and process innovations and their determinants from the five different perspectives that are explained above. In the analysis of Turkish manufacturing industry, the probit model with population-averaged estimator is used to analyze the panel data with binary dependent variables such as product (PD) and process (PC) innovation (if a firm introduces innovation—1, otherwise—0) with robust standard error method, within-unit exchangeable correlation structure (equal-correlation model), and confidence level 90 percent. To do this, panel data is generated from some micro data sets in A Group Data in TURKSTAT such as Annual Industry and Service Statistics (AISS), Research and Development Activities Surveys in Business Enterprise Sector (RDAS), Annual Industrial Products (PRODCOM) Statistics, and Innovation Survey (IS).

This dissertation includes five chapters. In Chapter I, the theoretical framework of the dissertation is provided by regarding R&D and innovation literature by focusing on technological change, research, firm characteristics, product and process innovation, and so on. In Chapter II, a bird's-eye view of science and technology (S&T) and R&D about Türkiye, and of Turkish Five-Year Development Plans (5YDPs) are presented. After that, detailed R&D statistics about Türkiye were elaborated and

supported by numerous figures. In Chapter III, research methodology and research design are explained in detail such as research model and hypotheses, micro data sets, panel data generation, and classification of Turkish manufacturing industry. For example, research models, hypotheses, data sets, panel data generation process, and independent variables are explained in detail. In Chapter IV, firstly, descriptive statistics is presented. After that, in the shadow of theoretical framework, research design, and research methodology, the results of the analysis of firms that engaged in R&D in Turkish manufacturing industry are presented from the perspectives of section C (as a whole perspective) and division (by industry), except manufacture of tobacco products that does not have any R&D activities in this panel data. In Chapter V, Turkish manufacturing industry is analyzed from the other perspectives such as classifications by TI, EII, and FS.

CHAPTER ONE

THEORETICAL FRAMEWORK

Certain economic concepts such as demand, supply, wants, needs, utility, profit, and production are ingrained in nature instinctively. In this sense, economy is an inseparable part of life. Because of technological developments, the world has changed unpredictably in terms of goods (products), processes (e.g., production and distribution), and relations. Product and process innovations are so precious to research in terms of manufacturing sector that there are producers and innovators. Today, the transition process of the world has continued hastily [e.g., the information and communication technology (ICT) age] through economic institutions with an increasing adoption capability of new technologies.

Economic institutions such as *firms* are one of the main parts of an economy. Economists sometimes emphasize it by using different terms such as: legal and administrative entity (Chandler, 1992) privately owned companies (Bernheim & Whinston, 2008), entity (Jehle & Reny, 2011), and organization (Case, Oster, & Fair, 2017). The main aim of the any individual firm managed by any entrepreneur/individual/owner is to produce outputs (the physical goods and services) by using inputs (the factors of production—such as capital, labor, natural resources, equipment, technology and so on) under the profit maximization decisions. This transformation occurs in the production process. Production is a technology or a process that converts production factors into outputs as a physical good or a service. Under their main aim, firms have two main crucial roles. One of them is to help countries in order to achieve their targets such as economic development, economic growth, employment, and so on from the macroeconomics perspective. The other one is to meet consumers' demand by producing goods and providing services. In this circulation, firms produce new/improved innovative products or provide new/improved innovative processes to get high profit thanks to monopoly rents, to

sustain its leadership in the market, and to meet demands in the market. This side of economics is a matter of microeconomics.

From the side of the country, countries use their own production factors to produce goods or services through firms. However, countries are different from each other in terms of distribution of the production factors. In a sense, every country has its own economic structure quantitatively and qualitatively; in other words, there are many differences in terms of characteristics of demand, supply, capital, labor, technology, and so on. Hall and Jones (1999) investigated reasons why there are differences among countries in terms of output per worker. According to their results, one of the reasons is differences in physical capital and education system among countries. The other reason is differences in social infrastructure (institutions and government policies that may provide a good economic environment where firms and individuals invest, R&D activities and knowledge transfer occur, and goods and services are produced) among countries that affects countries' capital accumulation, education systems, and productivity, and their income. These key differences among countries cause international economic relations such as technology transfer, foreign trade, and so on.

Countries that gain from international economic relations are mainly interested in their economic development and economic growth to improve economic well-being and quality of life for households and to increase real income. Economic growth is generally perpetual increase in real Gross Domestic Product (GDP) or in production capacity of a country in a year (Erdoğan, 2013). Economic development includes not only increase in real GDP as a quantitative dimension but also sociological, psychological, and political topics as qualitative dimensions in a country (Erden, 2012). In other words, economic development involves economic growth.

1.1. Literature Review on Economic Growth

The history of economic growth models can be reviewed briefly by separating models into four groups such as classical, neoclassical, and endogenous growth models. Then, we are going to relate the growth models with R&D activities.

1.1.1. Classical Growth Theory

Classical growth theory emerged during the period of the Industrial Revolution. According to Brewer (2010), classical views with no theory of continuing growth are based on Cantillon and Quesnay in France, and on Hume, Steuart, and Ferguson in Scotland. Brewer (2010) emphasized the importance of Turgot who introduced the definition of the classical theory of economic growth in 1766 before Adam Smith. According to Eltis (2000), classical growth theory is based on the ideas of Francois Quesnay, Adam Smith, Robert Malthus, David Ricardo, and Karl Marx. Francois Quesnay, as a physiocrat, emphasized the importance of agriculture and agricultural surplus based on new techniques (or productivity) as a source of economic growth (Eltis, 2000). In this process, according to Ricardo, new techniques in agricultural activities are important to increase output. Adam Smith, with his famous book “The Wealth of Nations” in 1776, introduced his thoughts that are based on specialization and division of labor and emphasized them as a source of productivity and therefore it leads to economic growth. In other words, with his absolute advantage theory, Smith focused on specialization and division of labor and therefore countries gain from international trade. Thomas Malthus emphasized the importance of population level that may cause poverty and less living standards. David Ricardo introduced the comparative advantage theory in 1817 by emphasizing production of more efficient goods/services that increases efficiency and productivity and therefore leads to economic growth. Karl Marx, who criticized the capitalist economic system radically, explained the source of economic growth that based on the exploitation of working class (labor), and this system creates wider income gaps in the society and lower purchasing power, and so on.

In classical growth theory, economic growth is based on the accumulation of capital and savings. It is seen that economic growth is related to the availability of land, labor, and capital.

According to Barro and Sala-i-Martin (2004), many of the fundamental components of modern economic growth theories are provided by classical economists

who contributed to the theory such as Adam Smith³, David Ricardo⁴, and Thomas Malthus⁵ in the late 18th and early 19th centuries, and other economists after them such as Frank Ramsey⁶, Allyn Young⁷, Frank Knight⁸, and Joseph Schumpeter⁹.

1.1.2. Neoclassical Growth Theory

In the 20th century, the neoclassical growth theory emerged and is based on building blocks that were provided by classical economists. The neoclassical growth theory also extended the classical one by focusing on the importance of technological progress that enhances productivity, thereby triggers economic growth.

According to Barro and Sala-i-Martin (2004), some economists such as Frank Ramsey, Roy Forbes Harrod¹⁰, Evsey David Domar¹¹, Robert Merton Solow¹², and Trevor Winchester Swan¹³ contributed to neoclassical growth theory between the 1920s and the 1950s.

Harrod (1939) tried to provide a framework of dynamic theory and Domar (1946) focused on the relationship between capital accumulation and employment. According to Barro and Sala-i-Martin (2004), Harrod (1939) and Domar (1946) tried to form an integration between Keynesian analysis and components of economic growth. After, their thoughts, their economic growth model was called the Harrod-Domar economic growth model. According to Solow (1956), the most important conclusion of the Harrod-Domar economic growth model is about the balance of

³ Adam Smith published his well-known book “*An Inquiry into the Nature and Causes of The Wealth of Nations*” in 1776.

⁴ David Ricardo published his well-known book “*On the Principles of Political Economy and Taxation*” in 1817.

⁵ Thomas Malthus published his study “*An Essay on The Principle of Populations, As It Affects the Future Improvement of Society*” in 1798.

⁶ Frank Ramsey published his study “*A Mathematical Theory of Saving*” in 1928.

⁷ Allyn A. Young published his study “*Increasing Returns and Economic Progress*” in 1928.

⁸ Frank Knight published his study “*Diminishing Returns from Investment*” in 1944.

⁹ Joseph Schumpeter published his well-known book “*The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest, and the Business Cycle*” in 1934.

¹⁰ Roy Forbes Harrod published his study “*An Essay in Dynamic Theory*” in 1939.

¹¹ Evsey David Domar published his study “*Capital Expansion, Rate of Growth, and Employment*” in 1946.

¹² Robert Merton Solow published his study “*A Contribution to the Theory of Economic Growth*” in 1956.

¹³ Trevor Winchester Swan published his study “*Economic Growth and Capital Accumulation*” in 1956.

economic system that is the best on a knife-edge of equilibrium growth, even in the long run.

Solow (1956) and Swan (1956) attempted to contribute to economic growth theory with their studies separately. According to Solow (1956), Harrod's analysis was about the comparing the natural growth rate (based on the growth of the labor force in the absence of technological advancements) with the warranted growth rate (determined by the savings and investment behavior of households and firm) but he used short-term tools to investigate long-term issues. The majority of Solow's study focuses on a long-term growth model that adopts all of the Harrod-Domar assumptions, except for the assumption of fixed proportions. Swan (1956) attempted to demonstrate the relationship between the growth of the productive labor force and the accumulation of capital. Later, this long-run economic growth model with neoclassical production function was called the Solow-Swan model. There are many predictions of the Solow-Swan model such as: conditional convergence that is important for explanation of economic growth across countries and regions, and cease of per capita growth in the lack of ongoing advancements in technology (Barro and Sala-i-Martin, 2004).

The Solow-Swan Model can be derived from the classical production function in closed economy case:

$$Y(t) = F[K(t), L(t), T(t)] \quad (1)$$

where $Y(t)$ stands for output produced at time t , $L(t)$ stands for labor, and $T(t)$ stands for technology. There are some definitions to understand the inputs better such as: K and L have rivalry characteristics; Capital means particularly durable physical inputs such as machines and buildings; Labor means human body as an input particularly such as number of workers, the amount of time workers work, workers' physical strength, workers' skills, and workers' health; Technology means formulas / blueprints such as knowledge or technology that improves over time, differs across countries, and has non-rival characteristics through basic public institutions (Barro and Sala-i-Martin, 2004).

Under the assumptions such as absence of international trade and equal rates of saving and investment (closed economy), and constant rate of depreciation of homogeneous capital good (δK , and $\delta > 0$), the change in capital stock over time (dynamics of K for a given technology and labor) means gross investment minus depreciation of capital. This capital accumulation can be explained as below:

$$\dot{K}(t) = I(t) - \delta K(t) = s \cdot F[K(t), L(t), T(t)] - \delta K(t) = s \cdot Y(t) - \delta K(t) \quad (2)$$

where $\dot{K}(t)$ is differentiation of $K(t)$ with respect to time(t) [in other words, the change in capital per period ($K_{t+1} - K_t$) continuously], the fraction of output that is saved (saving rate, s) is between zero and one.

The change in labor over time depends on many factors such as population growth (related with fertility, mortality, and migration), changes in participation rates, shifts in the amount of time worked by worker, improvements in workers' skills, and improvements in the quality of workers (Barro and Sala-i-Martin, 2004).

The neoclassical production function is based on some assumptions such as constant returns to scale (because technology has non-rival characteristics), positive and diminishing returns to private inputs, inada conditions¹⁴, and essentiality. Under these assumptions, the production function equation can be explained in per capita form

($\lambda = 1/L$) with no scale effects¹⁵ as below:

$$y = f(k) \quad (3)$$

where f is the per capita production function, y is the output per capita, and k is the capital stock per capita.

Main equation of the Solow-Swan Model can be found by dividing Equation 2 with labor (L) to express it in per worker form.

$$\frac{\dot{K}}{L} = s \cdot f(k) - \delta k = s \cdot y - \delta k \quad (4)$$

¹⁴ $\lim_{K \rightarrow 0} \left(\frac{\partial F}{\partial K} \right) = \lim_{L \rightarrow 0} \left(\frac{\partial F}{\partial L} \right) = \infty$ and $\lim_{K \rightarrow \infty} \left(\frac{\partial F}{\partial K} \right) = \lim_{L \rightarrow \infty} \left(\frac{\partial F}{\partial L} \right) = 0$.

¹⁵ The amount of physical capital per person is important to determine the total output per person. If k is constant, changes in the number of workers do not affect total output per person.

By taking derivative of capital-labor ratio (K/L) with respect to time (t), the equation can be acquired as below:

$$\dot{k} = \frac{\dot{K}}{L} - nk \quad (5)$$

where $n = \dot{L}/L$, and by substituting Equation 4 into Equation 5, main dynamic equation of the Solow-Swan model can be found as below:

$$\dot{k} = s \cdot f(k) - (n + \delta)k = s \cdot y - (n + \delta)k \quad (6)$$

According to this Solow-Swan model that explains the role of capital accumulation, the equilibrium point where gross investment equals to effective depreciation for k is called as steady state. In other words, determination of the change in capital per capita (k) is based on three terms such as: investment per capita ($s \cdot y$), depreciation per capita (δk), and decrease in capital per capita because of population growth (nk) (Jones and Vollrath, 2013). An increase in investment per capita leads to an increase in capital per capita, and depreciation per capita decreases the amount of capital per capita.

In this model, there are three different processes such as capital deepening (capital grows faster than labor, $k < k^*$, and $\dot{k} > 0$), capital widening (capital and labor grow at the same rate, $k = k^*$, and $\dot{k} = 0$), and non-accumulation of capital (labor grows faster than capital, $k > k^*$, and $\dot{k} < 0$), (Turan, 2008). According to the model, there are two important results such as: output and capital stock will continue to expand, but only at the same pace as population growth in the steady state equilibrium [$y^* = f(k^*)$]; and increasing the saving rate can lead to a temporary boost in the growth rate of the economy (output per capita), but this enhanced growth is not sustainable in the long run (Aghion and Howitt, 2009).

Introducing technological progress to this Solow-Swan model is important for generation of sustained economic growth. By using Cobb-Douglas form of production function with two inputs (capital and labor) and with a technology variable, A :

$$Y = F(K, AL) = K^\alpha (AL)^{1-\alpha} \quad (7)$$

where A is called as “labor augmenting” or “Harrod-neutral”, instead of “capital augmenting” or “Solow-neutral” $[F(AK, L)]$ and “Hicks-neutral” $[A \cdot F(K, L)]$ (Jones and Vollrath, 2013)

According to this technology added model, higher technology level leads to more productive unit of labor, but technological progress is exogenous. According to the model, on the balanced growth path, the rate of growth for both output per capita and capital per capita aligns with the growth rate of exogenous technological change ($g_y = g_k = g$) (Jones and Vollrath, 2013).

The Solow-Swan model that explains the role of capital accumulation with technological progress can be derived by using the production function as below:

$$\tilde{y} = f(\tilde{k}) \quad (8)$$

Where $\tilde{y}$ stands for output per capita-technology ratio ($Y/AL = y/A$), and $\tilde{k}$ stands for capital per capita-technology ratio ($K/AL = k/A$).

$$\dot{\tilde{k}} = s \cdot f(\tilde{k}) - (n + g + \delta)\tilde{k} = s \cdot \tilde{y} - (n + g + \delta)\tilde{k} \quad (9)$$

According to this Solow-Swan model that explains the role of capital accumulation with technological progress, the equilibrium point where gross investment equals to effective depreciation for $\tilde{k}$ is called as steady state and balanced growth path for an economy where ($g_y = g_k = g$), in other words (Jones and Vollrath, 2013). Therefore, in the long-run, countries experience growth of capital per capita at the rate of technological progress.

1.1.3. Endogenous Growth Theory

The neoclassical growth economists in the late 1950s and 1960s acknowledged the lack of modeling economic growth and commonly corrected it by supposing that technological progress took place externally or outside of the model.

Cass (1965) and Koopmans (1965) attempted to provide integration between Ramsey’s analysis of consumer optimization and the neoclassical economic growth model, which enabled the endogeneity of saving that does not remove the need for

exogenous technological progress to determine the long-run per capita growth rate (Barro and Sala-i-Martin, 2004). They investigated optimum growth, optimal rate of growth, and optimality criteria to maximize technology and population growth model (Cass, 1965; Koopmans, 1965).

According to Barro and Sala-i-Martin (2004), integration between the theory of technological change and the neoclassical economic growth theory is a challenging process because of unmaintainable typical competitive assumptions. Technological progress is related with many issues such as generation of new ideas and rivalry/non-rivalry matters. If new ideas were totally non-rival as a factor of production, typical competitive assumptions cannot be maintained, thereby non-rival ideas do not provide sufficient incentives for research effort (Barro and Sala-i-Martin, 2004).

Some economists, such as Arrow, Sheshinski, and Romer, discussed 'learning by doing', spill-over effect, and technological diffusion. Arrow (1962) and Sheshinski (1967) focused on models by emphasizing 'learning by doing' mechanism, in other words, ideas were unintentional outcomes that emerged as by-products of production or investment. Barro and Sala-i-Martin (2004) referred to these models that there are spill-over effects of inventions instantaneously under the non-rival knowledge assumption (in other words, under perfect competition environment). The studies on economic growth models focused on short-run issues during the period between the late 1960s and the late 1980s but perked up after this period (Barro and Sala-i-Martin, 2004). Moreover, studies on long-run economic growth model during the period of the late 1980s [such as Romer (1986) and Lucas (1988)] are generally based on studies in the 1960s [such as Arrow (1962) and Sheshinski (1967)], and they did not actually generate a theory regarding technological change (Barro and Sala-i-Martin, 2004).

Until the late 1980s, technology was exogenously included in economic growth models. During the period of the late 1980s, Romer (1986) and Lucas (1988) focused on development of long-run economic growth model. Romer (1986) stated knowledge as a key factor that has positive effect on marginal productivity and especially showed that technological progress rate is not Pareto optimal growth rate under competitive environment with externalities, in other words, knowledge increases marginal

productivity in the long-term for economic growth. In the light of Arrow (1962)'s idea, Lucas (1988) argued that knowledge accumulation is a source for sustainable economic growth.

Barro and Sala-i-Martin (2004) pointed out some economists [Romer (1987, 1990), Aghion and Howitt (1992), and Grossman and Helpman (1991a, 1991b, 1991c)] who are important for the integration among the neoclassical economic growth model, R&D theories, and imperfect competition framework. In other words, these studies focused on the determination of endogenous economic growth models.

Romer (1987, 1990), Aghion and Howitt (1992), and Grossman and Helpman (1991a, 1991b, 1991c) emphasized many issues such as technological progress based on R&D activity, reward after R&D activity as a monopoly power, and nonoptimal amount of R&D activity and rate of growth. In the light of these issues, governmental actions/regulations (e.g., *"taxation, maintenance of law and order, provision of infrastructure services, protection of intellectual property rights"*), and other regulations about international trade, financial markets, and the other economic matters are necessity for a long-term growth rate (Barro and Sala-i-Martin, 2004). By focusing on R&D, Romer (1990) precisely inserted R&D sector in the economic growth model and emphasized that some parts of human capital is separated for research [similar thought was mentioned by Phelps (1966)]. R&D activities are an endogenous factor in this endogenous growth model. Moreover, Griliches (1992) showed the existence of R&D spillovers that are a major source of endogenous growth model. It is possible to support R&D spillovers with governmental actions/regulations for a country. Knowledge and innovation are significant sources of technological progress and therefore of endogenous economic growth models. These sources can be supported by investment in education and R&D activity.

Neuhaus (2006) showed three-dimensional evolution of capital accumulation that is based on the processes of capital widening (mere capital accumulation) and capital deepening (technological change). In this study, he explained these three ways in detail under two capital accumulation forms such as: a) there is a process of capital accumulation known as "capital widening" where the focus is on increasing the

quantity of existing types of capital goods [Solow (1956) and Swan (1956)] rather than introducing new types; b) the other process of capital accumulation known as "capital deepening" as a form of technological change refers to either enhancing the quality of existing capital goods [Aghion and Howitt (1992)] or introducing entirely new types of capital goods [Romer (1990)].

1.1.3.1. R&D and Growth

Modeling the growth of technology variable (A) and the production of new technologies are based on the studies of Romer (1990), Grossman and Helpman (1991c), and Aghion and Howitt (1992) respectively, and it is based on four factors such as labor, capital, technology, and output (Romer, 1996). In this model, there are two sectors such as goods-producing sector and knowledge-enhancer R&D sector (Romer, 1996). The production function can be written as below:

$$Y(t) = [(1 - \alpha_K)K(t)]^\alpha [A(t)(1 - \alpha_L)L(t)]^{1-\alpha}, \quad 0 < \alpha < 1 \quad (10)$$

where $1 - \alpha_L$ stands for fraction of the labor force, and $1 - \alpha_K$ stands for fraction of capital used in goods production (Romer, 1996). A grows exogenously in the neoclassical model while A grows endogenously in the Romer's model.

The production of new ideas can be written as below:

$$\dot{A}(t) = G[\alpha_K \cdot K(t), \alpha_L \cdot L(t), A(t)] \quad (11)$$

This equation shows that quantity of capital, quantity of researcher (labor engaged in research), and technology level are necessary to produce new ideas (Romer, 1996). Its generalized Cobb-Douglas function form (production of new knowledge equation) can be written as below:

$$\dot{A}(t) = B[\alpha_K \cdot K(t)]^\beta [\alpha_L \cdot L(t)]^\gamma A(t)^\theta, \quad B > 0, \beta > 0, \gamma > 0 \quad (12)$$

where B stands for a shift parameter and A is stock of knowledge while $\dot{A}$ is number of new ideas produced. Replication of existing inputs makes technology level unchanged (diminishing returns in R&D), but many implementations such as interactions among researchers and fixed setup costs are significant in R&D (increasing returns in R&D) (Romer, 1996).

Under the assumptions of exogenous and constant saving rate, and zero depreciation, the change in capital stock over time can be explained by using Equation 2 as below:

$$\dot{K}(t) = s.Y(t) \quad (13)$$

and with exogenous population growth as below:

$$\dot{L}(t) = n.L(t), \quad n \geq 0 \quad (14)$$

According to model of new knowledge production without capital (dynamics of knowledge accumulation) and exogeneous labor growth:

- If θ is equal to one ($\theta = 1$): The production of new knowledge is proportional to the stock of knowledge. There is constant returns to scale. The 1% increase in the stock of knowledge (A) causes 1% increase in new knowledge production.
- If θ is bigger than one ($\theta > 1$): The effect of stock knowledge on the production of new knowledge is stronger. There is increasing returns to scale. The 1% increase in the stock of knowledge (A) causes more than 1% increase in new knowledge production.
- If θ is lower than one ($\theta < 1$): The effect of stock knowledge on the production of new knowledge is weaker. There is decreasing returns to scale. The 1% increase in the stock of knowledge (A) causes less than 1% increase in new knowledge production.

where θ stands for returns to scale to knowledge.

According to Romer (1987), specialization is important for increasing returns. By focusing on R&D, Romer (1990) precisely inserted R&D sector in the growth model and emphasized that some parts of human capital is separated for research ($L = L_Y + L_A$) [similar thought was mentioned by Phelps (1966)]. Researchers are human capital who is specialized in R&D activity that leads to increase in the stock of knowledge. In other words, the stock of knowledge can be increased by producing new

ideas that require more researchers in an economy. Then, production function for new ideas can be written as below:

$$\dot{A} = \theta L_A^\lambda A^\phi \quad (15)$$

where $\dot{A}$ is the number of new ideas produced that is multiplication of the number of researchers who attempt to discover new ideas (L_A^λ) with the rate at which they discover new ideas (θ), and where ϕ stands for standing on shoulders effect and λ stands for stepping on toes effect (Jones and Vollrath, 2013).

- In the case of constant productivity of researchers where $\lambda = 1$ and $\phi = 0$, the number of new ideas produced is equal to the multiplication of the constant rate at which finding new ideas and constant number of researcher, ($\dot{A} = \bar{\theta} L_A$). However, this rate of finding new ideas ($\bar{\theta}$) is constant in this equation, in other words, the pool of preexisting ideas that have been previously discovered. These preexisting ideas lead to increase in the productivity of researchers in the present.
- In the case of constant research effort where $\lambda = 1$ and $\phi = 1$, the number of new ideas produced is equal to the multiplication of the constant rate at which finding new ideas and constant number of researcher, and constant stock of knowledge ($\dot{A} = \bar{\theta} L_A A$). In other words, According to Romer (1990), constant research effort is important for a sustainable long-run growth, ($\frac{\dot{A}}{A} = g_A = \bar{\theta} L_A$), even if the rate at which finding new ideas and the number of researcher are constant.

According to Romer (1990), the stock of ideas that were invented in the past affects the productivity of researchers today, in other words, the existing stock of ideas influences the productivity of research. Romer (1996) stated that researchers and fixed setup costs are important for increasing returns in R&D. If the rate of finding new ideas ($\bar{\theta}$) is increasing function of stock of knowledge (A), it would be analyzed in detail and modeled as below:

$$\bar{\theta} = \theta A^\phi \quad (16)$$

where the rate of finding new ideas and stock of knowledge are constant. However, according to this model of the rate at which finding new ideas (Jones and Vollrath, 2013):

- If ϕ is greater than zero ($\phi > 0$): The productivity of research increases with preexisting stock of ideas that have been previously invented. It is known as positive knowledge spillover in R&D. Griliches (1992) showed the existence of R&D spillovers (ϕ) that are a major source of endogenous growth model.
- If ϕ is less than zero ($\phi < 0$): This is called as fishing-out case. It is explained as “*fish become harder to catch over time*” (Jones and Vollrath, 2013). In other words, the difficulty of catching fish increases over time. In R&D process, production of new ideas is hard, and occurrence of innovation is not easy.
- If ϕ equal to zero ($\phi = 0$): There is no dependency between the productivity of research and the stock of knowledge. In other words, the stock of ideas does not influence the productivity of researchers.

1.1.3.2. Human Capital and Growth

Human capital is one of the significant factors of economic growth and includes abilities, skills, and knowledge of some workers. Excludability and rivalry are prominent assumptions of human capital. Modeling the physical and human capital accumulation and growth is based on the Solow model and Cobb-Douglas production function under constant returns to scale assumption. As mentioned by Romer (1996), the model follows Mankiw, Romer, and Weil (1992)’s study and the production function can be written as below:

$$Y(t) = K(t)^\alpha H(t)^\beta [A(t)L(t)]^{1-\alpha-\beta}, \quad \alpha > 0, \beta > 0, \alpha + \beta < 1 \quad (17)$$

where H stands for the stock of human capital, L stands for the number of workers.

Under the assumptions of some portion of output allocated to the accumulation of physical capital (s_K) and no depreciation, the change in capital stock over time can be explained by using as below:

$$\dot{K}(t) = s_K \cdot Y(t) \quad (18)$$

and with exogenous population growth as below:

$$\dot{L}(t) = n \cdot L(t) \quad (19)$$

and constant and exogeneous technological progress as below:

$$\dot{A}(t) = g \cdot A(t) \quad (20)$$

and human capital accumulation over time can be explained as below:

$$\dot{H}(t) = s_H \cdot Y(t) \quad (21)$$

where s_H stands for some portion of resources allocated to the accumulation of human capital (Romer, 1996).

Nelson and Phelps (1966) emphasized the importance of education that enhances learning capability (receiving, decoding, and understanding information) of human capital and therefore educated labor or manager (mentioned as a good innovator) may accelerate adaptation of a firm to technological change by introducing new production processes under an agile strategy. They explained that there is a positive accelerative effect of education on technological diffusion, and the more technological progress the greater returns to education.

Cohen and Levinthal (1989) referred to R&D with two roles such as new information generator and enhancer of firm's technology adoption ability and of information utilization ability (learning/absorptive capacity). They emphasized that simplicity and structure of the learning process is significant for R&D expenditure and technological opportunities. According to them, there are three basic sources of technological knowledge such as internal R&D, knowledge from rivals' R&D spillovers, and knowledge from outside the industry. Cohen and Levinthal (1990) shed light on learning and innovation from a new perspective. In terms of sources of a firm's technical knowledge, they emphasized there are two factors that affect learning incentives such as the ease of learning and available knowledge quantity. According to them, ability to be conscious of the importance of new and external knowledge, ability to adopt it, and ability to implement it to commercial results affect firm's

innovative capability. In a nutshell, the learning environment of firms is significant in terms of R&D and its absorptive capacity.

According to Romer (1993), human capital and institutional framework based on educational system, firms, and R&D institutions are two important sources of absorption capability that is one of the characteristics of an economy in terms of endogenous growth theory. For instance, Foster and Rosenzweig (1996) showed that in India, educated labor catches on quicker and is more compatible with new technologies when compared with less educated labor, and there is a complementary relationship between technical change and investment in education.

Abilities, skills, and knowledge of workers and researchers can be increased with a formal education system that supports economic growth. R&D and research provide the accumulation of knowledge through researchers, scientists, engineers, and technicians, so a formal and productive education system is needed to increase their number and quality (Hayami and Godo, 2005). For instance, Sanchez-Sellero et al. (2015) showed that in Spain, if firms carry on their R&D activities in collaboration with universities, technology centers and if firms employ new graduates who studied in science, engineering, or technology and who are endowed with latest scientific knowledge, they give an outstanding performance with higher productivity.

1.2. Importance of R&D in Economic Growth

The sources of economic growth can be split into three categories from the perspective of traditional neoclassical growth theory such as (1) capital accumulation, (2) increase in labor quantity and quality, and (3) technological progress. These factors can cause economic growth through saving and investment, population growth and education, new and improved ways in technology, respectively. The first source of economic growth, capital accumulation, is the increase in real capital stock that occurs by saving some proportion of present income and then investing it to increase future output and income. Investments for capital accumulation can be separated into two subgroups such as directly productive investments (such as new factory, machinery, equipment, and materials) and incentive investments in social and economic infrastructure (such as roads, electricity, water, and communications). The second

source is about a more productive labor force. The last source, the most important one, is technological progress, in other words the increase in inventions and innovations (as a form of scientific knowledge) regarding physical and human capital (Todaro and Smith, 2015).

A country can acquire the technology by means of several ways such as importing capital goods, contracting with other countries that have further technology, employing foreign researchers within the country, and increasing research and development (R&D) activities. The best method among them for a country is to produce its own technology by performing R&D activities. R&D activities are a key source of long-run productivity and welfare through innovation (Jones and Williams, 2000). Subventions for innovation stimulate economic growth through R&D activities (Segerstrom, 1990). Investment in R&D to produce its own technology supports economic growth through the instrument of innovations (Shefer and Frenkel, 2005). Öztürk (2019) emphasized increase in the share of product and process innovations in Turkish manufacturing industry supports economic growth through increase in productivity. An increase in R&D activities can cause an increase in production possibilities and productivity. It can also lead to decrease in production costs through technological advancements. More R&D activities also support increase in the likelihood of occurrence of innovations and accelerate the process of innovations for product and process innovations. Most of theoretical and applied studies on technological innovations emphasized innovation and technology (and R&D) as an engine of growth (Schumpeter, 1934; Solow, 1956; Arrow, 1962; Phelps, 1966; Lucas, 1988; Romer, 1986, 1990; Aghion and Howitt, 1992; Romer, 1996; Ali and Hamid, 1996; Cameron, 1996; Jones and Williams, 2000; Freeman and Soete, 2004; Shefer and Frenkel, 2005; Kepenek, 2020). Coombs, Saviotti, and Walsh (1987) addressed that R&D is endogenous to economy. Freeman and Soete (2004) emphasized the importance of technology and innovation in terms of economic growth by mentioning Adam Smith's idea (technical change and division of labor), Karl Marx's idea (innovation in production technology), Alfred Marshall's idea (knowledge as an engine of production and economy), and Frederic Benham's idea (technical

advancements as driving force). Pece, Simona, and Salisteanu (2015) showed that there is a positive relationship between economic growth and innovation.

The stock of knowledge (existing ideas) can be increased by R&D activities. Thus, investment in R&D sector must be supported to produce new knowledge. New knowledge may increase the likelihood of introducing innovation (e.g., product and process innovation). It is a known fact that different types of knowledge such as basic scientific knowledge and progress, invention of applied technologies, invention of new products, and improvements in the design and use of products are an engine of economic growth through R&D activities and technological progress (Romer, 1996).

Technological progress can be discussed in two ways such as new products and quality improvements in existing products (Jones and Vollrath, 2013). Romer (1990)'s model focused on increase in the number of new intermediate goods while the models of Grossman and Helpman (1991c) and Aghion and Howitt (1992) focused on quality improvements in intermediate goods. The second one, alternative endogenous growth theory, is called the Schumpeterian model that explain replacement power of innovation with existing (old) goods. This process of replacement of new products/goods with existing (old) ones is called the process of creative destruction by Joseph Schumpeter in his book "Capitalism, Socialism and Democracy" published in 1942.

The structure of Schumpeterian model is explained explicitly by using the aggregate production function (similar to Solow and Romer model) as below (Jones and Vollrath, 2013):

$$Y = K^{\alpha}(A_i L_{\gamma})^{1-\alpha} \quad (22)$$

where A stands for the stock of ideas and i stands for ideas. Increase in ideas leads to a larger stock of ideas. For an example of TV and display technologies from black-white to color, if A_i is the recent available technology, A_1, A_2, A_3 , and A_4 stand for CRT TV (cathode-ray tube), PDP TV (plasma display panels), LCD TV (liquid-crystal display), LED TV (light-emitting diode), and moreover, OLED TV (organic light-emitting diode), QLED TV (quantum dots). Productivity increases with each

innovation, but innovation occurs in discrete steps rather than being a continuous process (as in the Romer model).

In the Schumpeterian model, the size of innovations remains unchanged. It can be explained as below:

$$A_{i+1} = (1 + \gamma)A_i \quad (23)$$

where γ stands for step size. According to this model, innovation is a driven force of economic growth. From an innovation to other innovation, the growth rate of the stock of ideas can be written as below:

$$\frac{A_{i+1} - A_i}{A_i} = \gamma \quad (24)$$

where the growth rate of the stock of ideas is not over time because the chances of occurrence of innovation is significant. These chances require research effort (Jones and Vollrath, 2013).

The individual likelihood of occurrence/discovering of innovation any time is represented by $\bar{\mu}$ in the Romer model as given, but the likelihood of occurrence of innovation is affected by “standing on shoulders” and “stepping on toes” and it can be written as below:

$$\bar{\mu} = \theta \frac{L_A^{\lambda-1}}{A_i^{1-\phi}} \quad (25)$$

where ϕ stands for standing on shoulders effect and λ stands for stepping on toes effect. For the economy as a whole, it can be written as below:

$$P(\text{innovation}) = \bar{\mu}L_A = \theta \frac{L_A^\lambda A_i^\phi}{A_i} \quad (26)$$

where there are two effects of the stock of ideas on the likelihood of occurrence of innovation any time, and L_A stands for the number of individual researcher (Jones and Vollrath, 2013).

The Schumpeterian model, as a model of imperfect competition model, refers to three sectors such as final-goods, intermediate-goods, and research by underlying the creative destruction approach. According to this model, there is a process like: 1) a firm may produce monopolistic intermediate goods by having its patent that prevents

the replacement of the firm with new ones; 2) This capital good is an input to produce final goods and it can be innovated and improved by researchers in the research sector; 3) The patent of this more productive capital good can be sold to a firm in order to produce this monopolistic intermediate goods (Jones and Vollrath, 2013).

In the light of these relationships among country, firm, and economy, and in the shadow of Schumpeter, the theoretical framework is based on both micro and macro perspectives because R&D activities, innovation, and knowledge accumulation are related to issues in micro and macroeconomics such as firm innovativeness and economic growth. Yay and Gürkan Yay (2022) pointed out that Schumpeterian paradigm is a kind of bridge between micro and macroeconomics because the paradigm that is related with the theory of the firm and entrepreneurship based on innovation, learning, and knowledge, economic growth, and international trade. They underlined the Schumpeterian economics that is interested in technological innovations, firm size, and interindustry relations. In this sense, it is necessary to analyze firms to support the development process of economic policies on technological research and progress in terms of industrial economics.

1.3. Discussions on The Role of Technological Research and Innovation

In the Shadow of Schumpeter, Maclaurin¹⁶ (1942) summarized considerations about the role of technological research in American economy in a conference on economics of industrial research. In this sense, attendees considered many topics such as the importance of basic scientific research, the training of scientists, tax incentives for research, and problem of motivating the businessman, by focusing on post-war planning for manufacturing and on investment opportunities. As suggested by Schumpeter (1934), the need for analysis on entrepreneurial motivation and environmental conditions in manufacturing was emphasized in this meeting.

¹⁶ Maclaurin's studies were reviewed shortly in terms of technological change and innovation in the shadow of Schumpeter (Godin, 2008).

After the conference, discussions on the topics started to increase more. Cole (1942) inquired many questions about entrepreneurial activities but focused mostly on the meaning of entrepreneur or entrepreneurship by emphasizing the desirability of research in the history of American entrepreneurship. Rosenstein-Rodan (1943) explained arguments for the successful carrying out of industrialization such as the importance of training and skilling of labor as a first task of industrialization. Following Schumpeter's emphasis on the critical significance of innovations in economic development and Cole's stimulus efforts to create a group of researchers who interested in entrepreneurship, Maclaurin (1950a) discussed the process of innovation and entrepreneurship by emphasizing the importance of scientific entrepreneurship and scientists who ask and investigate scientific questions skeptically, and by explaining lack of qualities of the inventor-entrepreneurs. In another study, Maclaurin (1950b) noticed that patent system protects monopolistic power of large firms but discourages invention in other words more competition causes greater technical and technological progress. Under the Schumpeter's view, Maclaurin (1953) explained the process of technological advance (progress) with measurable elements such as the propensity to develop pure science, the propensity to invent, the propensity to innovate, the propensity to finance innovation, and the propensity to accept innovation. In measuring the propensity to innovate, Maclaurin (1954) suggested new firms and existing firms to analyze innovations over time industry by industry. Upon this suggestion, Maclaurin (1954) analyzed thirteen American industries qualitatively by classifying with respect to rate of technological progressiveness, monopolistic features, branch of engineering, and source of entrepreneurial background. In this analysis, he developed a three-level (high, medium, and lower) classification of manufacturing industries with respect to technological progressiveness (based on volume of R&D expenditure, number of patents issued, and number of scientist), and defined technological progress (change) as the introduction of important new or improved products or processes (product or process innovation). Nutter (1956) expressed that some product and process innovations are based on great risk and R&D expenditure and discussed the amount of R&D expenditure as an index of innovational activity.

Market structure and firm size are important issues that were discussed by Schumpeter (1934) and Maclaurin (1950b) in terms of determining effective economic policies for industries. Villard (1958), who supported the policy of large oligopolists for more private research (except monopoly), pointed out a different way of process of innovation when compared with Maclaurin (1950b), which is a combination of government encouragement of research and increasing industrial concentration that depends on co-operative research and private research expenditures. Schmookler (1959) criticized Villard (1958) and confirmed an idea that is no connection between firm size or industrial organization and the likelihood of technical progress. Villard (1959) replied Schmookler (1959) and emphasized that stimulation of R&D is based on firm size that concept was used as industry not firm. Worley (1961) highlighted the concept of new competition that depended on the view of large oligopolistic worries¹⁷ such as pressure of rivals and loss of competitive advantage. These are main sources of technological change thanks to product and process innovations that came out of research in R&D laboratories. Horowitz (1962), who was one of the advocates of the idea that firm size promotes research, analyzed firms to clarify the connection among market structure (CR4), R&D intensity (R&D expenditure/sales), and technological progress, and empirical results of his analysis¹⁸ underlined the idea. Mansfield (1963) analyzed the effect of market structure on the rate of technical progress in some industries (e.g., iron and steel, and petroleum refining and bituminous coal) from the perspective of product and process innovations to present the relationship among firm size, market structure, and these innovations. According to the study, a huge part of innovations does not belong to the largest firms in the industry.

Together with innovation and R&D activities, knowledge accumulation has a key and strategic role for technological change and long-term and sustainable economic growth and development. Importance of knowledge, knowledge

¹⁷ Concerns of large oligopolistic firms are to feel under pressure to attempt R&D and to innovate in order not to be lost its competitive advantage against its rivals. Worley (1961) mentioned some promoters of this view such as Schumpeter (1942), Lilienthal (1952), Galbraith (1952), and Kaplan (1954).

¹⁸ He used rank correlation analysis described by Kendall (1948) and establishment size as a measure that introduced by Niehans (1958). He used “the ratio of R&D expenditure to sales” and “the ratio of R&D employment to sales” as the measure of research intensity.

accumulation, and labor force who accumulates knowledge through R&D activities (researchers) is highly discussed topic in technological progress literature. Solow (1957) defined technical change as improvements in the education of the labor force, a few years after Rosenstein-Rodan (1943)'s emphasis on training and skilling of labor and Maclaurin (1950a) emphasis on scientists. Under the view of educated labor in R&D, Nelson (1959) pointed out basic research in the economy and the allocation of R&D resources for it by emphasizing the comparative advantage of university laboratories for society. In the light of the terms such as know-how and practicing, Arrow (1962) emphasized the concept of "*learning by doing*" in other words learning (skill) as a source of technological change is "*a product of experience*" or "*learning by using*". For example, a labor can increase his/her learning skill by gaining experience of a production process where he/she works on. According to him, education and research institutions also accelerate acquisition and accumulation of knowledge.

In the period especially from the 1940s until the 1960s, researchers have focused on understanding the meaning of entrepreneur or entrepreneurship, the sources of economic growth and development, and the importance of innovation process, education for labor productivity, patent system, measuring technological change, R&D expenditure, firm size, market structure, product and process innovation etc.

Understanding the sources of economic growth and studying R&D, innovation, firms, and market structure are two important points for economic development policies regarding R&D-based (knowledge-based) and technology-based development strategies. Developed and developing countries have considered these topics increasingly. According to common inferences, considerations on determination of effective policies on R&D, technology, and innovation showed that well-designed data and its analysis in the most correct way are required to understand R&D activities. In this sense, investigation of firms and industries in an economy is significant to understand them and to develop efficient policies on R&D activities, technology, and innovation. In other words, to understand firms and industries and to develop effective policies, countries must analyze their R&D activities and innovation data. For this very reason, after many discussions among countries and experts, OECD NESTI agreed on

Frascati Manual in 1963. Frascati¹⁹ Manual²⁰ is one of the valuable products of discussions on R&D and innovation.

Innovation is a nonlinear process and technological change has complex and heterogeneous characteristics (Archibugi and Pianta, 1996). The necessity to analyze and to study innovation and firms has been emphasized many times by researchers and the number of these studies has increased gradually since the first half of the twentieth century. They have pointed out importance of understanding and investigating of innovation and firms' innovativeness in an economy regarding sectoral differences to develop efficient policies on R&D and innovation which support economic development and economic growth (Schumpeter, 1934; Maclaurin, 1942, 1950a, 1950b, 1953, 1954; Cole, 1942; Hamberg, 1964; Taymaz and Saatçi, 1997; Freeman and Soete, 2004). Schumpeter (1934) strongly discussed the importance of innovation and innovative entrepreneurship by dividing technological change into three parts [mentioned by Arthur (2007)] such as invention (creating), innovation (commercialization) and diffusion (spreading). He, as one of the research fire starters, emphasized adamantly the importance of studies on these topics for economy by igniting his descendent researchers and sagaciously separated innovation²¹ into five types [remarked by Kennedy and Thirlwall (1972) and Feeny and Rogers (2003)] such as: a) new product innovation / a qualitative change in an existing product; b) new process innovation to an industry; c) new markets and marketing methods; d) changes in the law, development of new sources; and e) changes in the methods of business / industrial organization. Gopalakrishnan, Bierly, and Kessler (1999) reviewed the characteristics of process and product innovations and explained that the former one is more complex and systematic, internally sourced, costly to implement, and effective than the latter one.

¹⁹ Frascati is a city and commune near Rome in the Lazio region in Italy. There are many laboratories in the city. The meeting for the manual was at the Villa Falconieri in 1963.

²⁰ Frascati Manual was first agreed as a methodology for collecting and using R&D statistics by OECD NESTI in 1963.

²¹ Archibugi and Pianta (1996) provided four different criteria (perspectives) to classify innovation after many decades such as technology (technical characteristics of innovation), product (nature of the product), sector of production (main economic activity of the firm), sector of use (main economic activity of the users).

1.4. Studies on R&D and Innovation in the World

The process of understanding firms and industries by investigating R&D activities and innovation, is not only supported by institutions (such as OECD and EUROSTAT) but also researchers who are interested in them. So, studies on R&D and innovation continue to grow and expand with each passing year.

1.4.1. Studies in the Period Between the 1960s and the 1970s

In the 1960s, researchers have continued to publish many studies by investigating and analyzing R&D activities and innovations from different perspectives (additionally, related to R&D expenditure, firm size (e.g., small, medium, and large), market structure (e.g., the imperfect competition such as oligopoly and monopoly) education, patent, productivity, growth, etc.). Each of these studies will be reviewed here chronologically.

Hamberg (1964) defended the large oligopolistic firms that are the main source of R&D with highly skilled scientists and engineers, full-fledged laboratories, and personnel, and stated that firm size is one of the significant determinants of R&D activities. He analyzed American manufacturing industry by two and three-digit industry classification to clarify the relationships between R&D and firm size, and between R&D and market structure. He showed that there are positive relationships between R&D expenditure and market structure (the degree of industrial concentration, CR4), between R&D intensity (R&D expenditure/sales) and market structure, between R&D employment and firm size (employment and sales), between R&D employment and firm size (sales), and between R&D intensity (R&D employment/total employment) and firm size (employment).

McConnell and Ross (1964) specified that larger firms engage in R&D more than smaller firms, and that smaller firms assign larger percentage of their employees to R&D than larger firms, by classifying²² American manufacturing industry by

²² According to this classification, the biggest four industries (high research industries) that have the greatest frequencies are instruments, electrical machinery, machinery, chemicals while the low research industries are leather products, textile mill products, petroleum and coal products, lumber and products, printing and publishing, and food and kindred products.

relative frequency of R&D that was undertaken. They proved that there is no clear relationship between relative frequency of R&D that was undertaken and research objectives²³. However, firms focused more on the improvement of existing products (Schumpeterian perspective) than development of new products (Romerian perspective).

Mansfield (1964) investigated the determinants of a firm's R&D expenditure level (in other words R&D intensity: R&D expenditure/sales) and proved that there is no relationship between firm size (by sales) and R&D intensity but a relationship between firm size and firm's inventive output. He found a correlation between the effect of R&D intensity and firm's inventive output in chemical industry but no evidence in petroleum and steel industries.

Markham (1965) stated a firm's innovational effort in terms of its R&D expenditure and investigated the relationship between R&D expenditure and market power, who defined himself together with Horowitz (1962), Mansfield (1963), and Hamberg (1964) as unsure the researchers according to results.

According to Scherer (1965a), the sample in the analysis of Worley (1961) and Hamberg (1964) was not random and exhaustive, and he used the number of patents variable (instead of R&D employment) as an inventive output, like Maclaurin (1954). Scherer (1965b) showed that inventive output (patents) has a positive relationship with sales (generally at a less than proportional rate) and described differences in technological opportunity as a main factor that causes interindustry differences in inventive output and expressed that there is not systematically relationship between inventive output (patents) and market power in terms of technological change.

Nelson and Phelps (1966) emphasized the importance of education that enhances learning capability (receiving, decoding, and understanding information) of human capital and therefore educated labor or manager (mentioned as a good innovator) may accelerate adaptation of a firm to technological change by introducing

²³ e.g., to improve existing products, to develop new products, and to develop new productive equipment and processes.

new production processes under an agile strategy. They explained that there is a positive accelerative effect of education on technological diffusion, and the more technological progress the greater returns to education.

Phelps (1966) separated researchers (as investment in technology) from labor force and stated that increase in productivity of researchers causes technological progress [like Maclaurin (1950a)'s emphasis on need for scientists]. In other words, the speed of knowledge accumulation may be increased thanks to researchers' ascending productivity.

Nordhaus (1969) described invention as a new process of production, a new vector, or activities that raises technical knowledge. He analyzed the railroad and agriculture industries by using the annual number of patents issued (as a proxy for the number of inventions) and found that they were positively correlated with an increase in output and negatively correlated with productivity levels.

Subrahmanian (1971) analyzed Indian chemical industry in terms of market structure, firm size, and technological progress, and used variables such as R&D intensity (R&D expenditure/*turnover*) and firm size²⁴. According to the study, there is no evidence of the relationship between firm size (absolute and relative) and R&D intensity.

Soete (1979) investigated the relationship between firm size and inventive activity, and R&D expenditure is used as a measure for inventive activity. According to this study, there is a positive relationship between inventive activity and firm size.

Studies on R&D activities became deeper than before as a result of increasing availability of R&D statistics after the determination of a methodology for collecting and using R&D statistics in 1963 by OECD, called the Frascati Manual. Firm-level and sector-level analyses on R&D activities started to increase related to education, patents, adaptation of a firm and technological diffusion [third part of technological change, according to Schumpeter (1934)] were considered.

²⁴ In this study, firm size is determined by total assets and total turnover (absolute size), and market power (relative size)

1.4.2. Studies in the Period Between the 1980s and the 1990s

In the 1980s, under the effect of globalization, the world changed dramatically at the global level in terms of economical, technological, political, and sociological aspects. International trade has started to boom in the light of developments about free trade ideas such as free trade agreements and reducing tariffs. Deregulation and privatization policies together with international trade and an increase in investment have supported economic growth. Under these radical changes in the world, adoption of technologies (inventions and innovations) such as personal computers and the internet has become widespread. Moreover, these changes have spurred production in the manufacturing industries together with automation, computerization, outsourcing, quality control, and lean manufacturing etc. All these developments provide new roads for researchers to analyze manufacturing industry in more detail in terms of R&D and technological innovations that is described as a key to productivity by Avard, Catto', and Davidson (1982). In 1992, OECD NESTI and EUROSTAT agreed on Oslo Manual²⁵ that is one of the valuable products of discussions on R&D and innovation after the Frascati Manual in 1963.

Mansfield (1981) investigated the relationship between the composition of R&D expenditure and three different variables separately, such as firm size, market structure (CR4, industrial concentration), and innovative output. In this study, R&D expenditure was considered in terms of four types²⁶ of R&D. As a result of the study, there is a positive relationship between firm size and percentage of R&D expenditure on basic research, and negative relationship with ambitious R&D. He showed that more concentrated market structure brings different strategies among firms in terms of the composition of R&D, and additionally, in chemical and petroleum industries, holding firm's R&D expenditure constant, there is a relationship between firms'

²⁵ Oslo Manual, agreed in the early 1990s, is a guideline for collecting, reporting, and using data on innovation in OECD countries, EU countries, and non-member economies. It was revised several times and the last revision (fourth edition) was released in 2018 by OECD and EUROSTAT. In this manual, innovation was separated into a few types such as product innovation, business process innovation, and so on.

²⁶ Four types of R&D are basic (basic research), long-term (project lasting five or more years), ambitious (projects aimed at entirely new products and processes), and risky (projects with less than a 50-50 estimated chance of success).

innovative output and the percentage of its R&D expenditure on basic research. After showing the importance of R&D expenditure for basic research in terms of innovation, Mansfield (1982) pointed out the effects of tax policy on R&D and the rate of innovation in terms of its contribution to economic growth. Mansfield (1986) showed that R&D tax credit helped to increase industrial R&D in the US. Mansfield (1983) emphasized that technological change is one of the main factors that affect market structure and described the percentages of product and process innovations as ‘concentration-increasing’ and ‘scale-increasing innovations’, respectively. He used, instead of the rate of productivity increase, both the ratios such as the ratio of R&D expenditure to sales and the ratio of R&D expenditure to value-added as measures of the rate of technological change and showed that there is no relationship between the ratios and those product and process innovations.

Kaplinsky (1983) pointed out that the relationship between firm size and technical change varies between different stages of growth cycle. He stated that the innovativeness role of small, medium-sized, and large firms changed from the 1950s to the early 1980s in the computer-aided design (CAD) sector.

Pavitt (1985) used patent statistics as a proxy for innovative (technological) activities, economists like Maclaurin (1954), Scherer (1965a) and Schmookler (1966), to reveal the relationship between international patterns of innovation and R&D activities and international patterns of trade and production.

Lunn (1986) investigated the relationship between innovation and market structure by separating innovations into two groups such as process and product innovations. He showed that there are differences for both innovations in the results of the analysis such as a positive relationship for process innovation but no relationship for product innovation. Moreover, there is a weak relationship between advertising (significant to increase demand) and product innovation in this study.

Pavitt, Robson, and Townsend (1987) investigated the relationship between innovative activity and firm size. They used independent variables such as R&D intensity (the proportion of net output in each sector spent on industry funded R&D), plant size, technological ease of imitation (the proportion of innovations made in each

sector by firms), users' innovation (the proportion of innovations in each sector made by user firms outside the sector), and dependent variables such as percentage of innovations by firms in a sector with the number of employees²⁷. According to the study, there is a U-shaped relationship between innovative activity and firm size.

Acs and Audretsch (1988a, 1988b) investigated the effects of market structure on innovative activity (innovation rate: number of innovation / industry employment) and showed that there is a negative relationship between market structure and innovation activity, and a U-shape relationship between innovation and firm size. They also showed the share of R&D expenditure in sales (R&D expenditure/sales) by sectors and explained that there is a positive relationship (closely related) between R&D expenditure and innovative output.

Silverberg, Dosi, and Orsenigo (1988) underlined the importance of Schumpeterian entrepreneur in the innovation process in terms of diffusion (fundamental for growth process) of product and process innovations within and between firms that were separated into two groups such as adopters and non-adopters.

Dosi (1988) also pointed out research processes, determinants of technological change models, and sectoral differences. He referred to differences among sectors due to many reasons such as costs of R&D processes, diffusion of information, technological capabilities, externalities regarding learning by doing and learning by using, and adoption of innovation. In the sense of sectoral differences, the importance of share of R&D expenditure (or resources as a broader meaning) and rate of introducing product and process innovations are called as the propensity to innovate by Dosi (1988), which is one of the measurable elements of technological progress (Maclaurin, 1953).

Cohen and Levinthal (1989) referred to R&D with two roles such as new information generator and enhancer of firm's technology adoption ability and of information utilization ability (learning/absorptive capacity). They emphasized that

²⁷ They categorized the firms by the number of employees such as Very Large innovating firms stand for 50.000 and more employees, Large innovating firms (10.000 and more), Small innovating firms (1000 and less), and Very Small innovating firms (200 and less).

simplicity and structure of the learning process is significant for R&D expenditure and technological opportunities. According to them, there are three basic sources of technological knowledge such as internal R&D, knowledge from rivals' R&D spillovers, and knowledge from outside the industry. Cohen and Levinthal (1990) shed light on learning and innovation from a new perspective. In their model of sources of a firm's technical knowledge, there are two factors that affect learning incentives such as the ease of learning and available knowledge quantity. They stated some critical abilities of a firm that affect its innovative capability such as being conscious of the importance of new and external knowledge, adopting it, and implementing it to commercial results. They analyzed the American manufacturing sector R&D activities data by using R&D intensity²⁸ as a dependent variable. In their model of business-unit R&D intensity, they explained three factors of industry-level determinants of firms' R&D expenditure such as technological opportunity, appropriability, and demand conditions. According to their empirical analysis on R&D investment, the learning environment of firms is significant in terms of R&D and its absorptive capacity.

Santarelli and Sterlacchini (1990) analyzed Italian manufacturing industry firms with more than 20 employees in terms of innovation diffusion by mentioning formal and informal R&D during the period 1981-1985, and showed that large firms that conduct systematic research and have well-structured and institutionalized R&D laboratories are more efficient for product innovations than small firms that conduct occasional R&D.

Griliches (1990) discussed patents, patent statistics and system, and classification patents by firms, groups, and industries, like Maclaurin (1954), Scherer (1965a), Schmookler (1966), and Pavitt (1985). According to the study, there is a strong relationship between R&D expenditure and patent numbers from the cross-sectional perspective, and patents are stated as an important indicator to explore the differences in R&D activities among firms.

²⁸ R&D intensity was interpreted as business-unit R&D expenditure that is financed by company, and was stated as a percentage of business-unit sales and transfers [R&D expenditure / (Sales+Transfers)]

Audretsch and Acs (1991) investigated the relationship between innovation output and firm size by splitting industries into two groups with respect to R&D intensity (R&D expenditure/sales) such as high-tech and low tech. They showed that there are different results in both industries in terms of investing in stock of knowledge such as high-tech industries invest small amount while low-tech industries invest significant amount.

Grossman and Helpman (1991a) established a model about product improvements that follow quality stairs, and described product innovation as a process that generates an ever-expanding range of horizontally differentiated products. In their other study, Grossman and Helpman (1991b) developed a model of dynamic life cycle process between the North and the South by mentioning Vernon (1966), and determination of length and speed of introducing new products to the market is emphasized as an endogenous process with this model.

Romer (1993) referred to poverty issues in developing countries from two perspectives that explained the reason why a country is poor such as not only object gaps but also idea gaps that are important for economic development. The former one is about the lack of factories, roads, and raw materials in a country. The latter one is about obstacles for accessing economic value generator ideas. According to Romer (1993), human capital and institutional framework based on educational system, firms, and R&D institutions are two important sources of absorption capability that is one of the characteristics of an economy in terms of endogenous growth theory.

Acs, Audretsch, and Feldman (1994) investigated university and firms R&D spillovers to innovative activity in terms of firm size and geographic location. They emphasized that the location between universities and research laboratories is significant for innovation activity of all firms. When they are close to each other, they have catalyzer effect on innovation activity of all firms. In generating innovation activity, they also showed that R&D activities of firms are more important for large firms and R&D spillovers has a decisive effect for innovation activities of small firms.

Griliches (1994) discussed the sources of productivity growth such as labor and capital quality improvements, efficiency, and technical change. Public and private

R&D expenditure (formally and informally) and science are significant for technical change, and spillovers of R&D for efficiency. From this perspective, expenditures and investments on education, science, and R&D activities of firms are necessary to maintain technical change continuity.

Foster and Rosenzweig (1995) discussed topics such as learning by doing and learning from others with a panel data from a sample of Indian households (farmers) in agriculture to investigate learning externalities. They showed that imperfect knowledge in management process is an obstacle for adoption of new varieties, this obstacle diminishes as new technology is used, experience of farmers and their farmer neighbors is significant for increase in profitability.

Bertschek (1995) investigated the effect of import and foreign direct investment on process and product innovation activities by using random effect probit approach for 1270 firms in German manufacturing industry between the years 1984-1988 and showed that there is a positive and significant effect of these variables on both innovations.

Cameron (1996) considered several innovation measures such as R&D expenditure, patents, number of innovations, effect of technological spillovers, who emphasized many issues with empirical evidence such as innovation as a source of economic growth, importance of spillovers among countries, firms, and industries, and localization of the spillovers.

Audretsch and Vivarelli (1996) analyzed Italian regions in terms of innovative inputs (R&D expenditure) to innovative outputs and showed that there is a positive relationship between innovative output of firms and R&D expenditure, and private R&D expenditure are more effective in R&D activities in large firms while R&D expenditure on university-based research are a key factor for small firms.

Audretsch, Menkveld, and Thurik (1996) investigated 1106 Dutch manufacturing firms' (engaging in R&D) decisions to invest in internal and/or in external R&D. As a result of their analysis, there are differences between high-tech industries and low-tech industries in terms of investment characteristics. Internal and external R&D complement each other in the former industry while both R&D

substitute for each other in the latter one. Internal R&D is significant to transform external knowledge into firms' knowledge stock (innovation opportunity) while external R&D is related with spillovers effect. They also showed that there is a positive effect between R&D personnel and the probability that firms engaging internal and external R&D.

Kumar and Saqib (1996) analyzed 291 Indian firms to reveal the determinants of the probability of undertaking R&D activity and R&D expenditure intensity in Indian manufacturing industry by using probit model. They used factors such as firm size, technology imports, export orientation, appropriability, accumulated learning, opportunities for process and product adaptations. According to the study, there is a positive relationship between the probability of undertaking R&D and firm size (up to a certain level, in other words nonlinearly), between R&D intensity and firm size (linearly).

Foster and Rosenzweig (1996) discussed technical change and education by analyzing it with sample of more than 4000 rural households in India between the years 1968-1981. According to their analysis, educated labor catches on quicker and is more compatible with new technologies when compared with less educated labor, and there is a complementary relationship between technical change and investment in education.

Vonortas and Xue (1997) researched process innovation in US firms' experiences whether they use or invest in CNC²⁹ (Computer Numerical Control) machine or not, to understand factors and problems (technical, economic, or organizational) that affect their investment decisions in CNC and their adoption of a process innovation. They emphasize that adequate in-house technical expertise is significant to adapt and to adopt CNC machines, and technology diffusion strategies such as demand-pull and technology-push are implemented together.

²⁹ Vonortas and Xue (1997) explained that computer Integrated Manufacturing (CIM) technologies comprises computer-aided design/manufacturing (CAD/CAM), computer numerical control (CNC), industrial robots and other material handling devices.

Crepon, Duguet, and Mairessec (1998) investigated French manufacturing firms to reveal relationship among productivity, innovation and R&D and provided three relationships such as research relation (research-its determinants), innovation relation (research-innovation output measures), and productivity relation (innovation output to productivity). According to their results: firm size (by the number of employees), market share of a firm, and demand-pull (demand conditions) and technology-push (technological opportunities) indicators are positively related to the probability of firm engaging in R&D and its R&D capital intensity (research effort); research effort of a firm, demand-pull and technology-push indicators are positively related to firm innovation output (patent numbers or innovative sales).

Bonanno and Haworth (1998) focused on explaining of a model of vertical differentiation to analyze intensity of competition [under Bertrand (more intense) and Cournot (less intense) competition) and the choice of a firm between product and process innovation. According to their results, cost-reducing innovations are maintained under less intense competition, and high-quality firm chooses product innovation under more intense competition environment and process innovation under less intense competition while for low quality firm it is vice versa.

Martinez-Ros (1999) investigated Spanish manufacturing firms for the years between 1990-1993 to investigate the determinants of innovation activity for product and process innovations. According to the study, the probability of occurrence of innovation is higher for capital-intensive firms and for firms conducting export activities, market competition is important factor to spur the decision to innovate, the probability of occurrence of innovation is affected by managerial quality and experience of firm, decisions for both innovations are complementary.

1.4.3. Studies After 2000

In the twentieth century, S&T has changed irresistibly, and competition has surged rapidly. Competition in many fields among countries and firms requires to incent R&D activities, education, and research to have an advantage of competitiveness. R&D, education and research institutions are necessary for learning and rapid knowledge accumulation. The speed of learning skill and knowledge

accumulation is not only related with structure of the institutions but also characteristics of labor or/and researchers. Investments in education of labor force improve their productivity, and investment in R&D activities foster innovation, and both can accelerate knowledge accumulation process in turn contribute to economic growth and development. Romer (1986) highlighted that knowledge is a key factor that increases marginal productivity in the long-term for economic growth, and specialization is important for increasing returns (Romer, 1987). In the light of Arrow (1962)'s idea, knowledge accumulation is a source for sustainable economic growth according to Lucas (1988). Moreover, Griliches (1992) showed the existence of R&D spillovers that are a major source of endogenous growth model. By focusing on R&D, Romer (1990) precisely inserted R&D sector in the growth model and emphasized that some parts of human capital is separated for research [similar thought was mentioned by Phelps (1966)]. However, according to Ülkü (2007), increase in the share of researchers in labor force causes increase in innovation but only in OECD countries that have large market. Heshmati and Kim (2011) also showed that there is a two-way causal relationship between growth in R&D investment and growth in labor productivity.

Aghion and Howitt (1992) specified six different ways of knowledge accumulation such as:

- formal education,
- on-the-job training,
- basic scientific research,
- learning by doing,
- process innovations, and
- product innovations.

Under the view of Arrow (1962), Phelps (1966), Romer (1990), and Aghion and Howitt (1992), advancements in S&T require:

- well-equipped R&D laboratories,

- a professional and qualified team that includes (real) skilled members such as scientists and engineers, and
- assistant personnel to support the team.

All these developments are called as “*Research Revolution*” by Freeman and Soete (2004).

In the light of developments in the twentieth century, significant changes were seen in manufacturing industries in the world in the 2000s such as increase in automation, more outsourcing and offshoring policies, wide spreading adoption of lean manufacturing, increase in sustainability and environmental issues regarding waste, emissions etc., and the last but not the least industry 4.0 and developments in digitization captured the production processes and daily life such as internet of things (IoT), data analytics, data mining, and machine learning algorithms, artificial intelligence (AI) and so on. New technologies have been produced and developed rapidly. For example, developments in ICT such as smart techs, cloud computing, social media etc. have become a part of human life rapidly. Countries and firms have increased their investments in ICTs and R&D activities a lot to gain a more competitive advantage. Countries use their factors of production to conduct R&D activities in universities, government laboratories, and firms. When firms introduced new products or processes, firms took some advantages such as less cost of production and increase in market competitiveness. There are many reasons for a firm to spend its resources on R&D for process (new production techniques) and product innovations such as innovation opportunities, expectation of possibilities for new market creation of its product and process innovations, and economic returns (Dosi, 1988). Under these reasons, there is more complex and competitive business life that require more investments in R&D in many industries such as pharmaceuticals, biotechnology, renewable energy, transportation, aerospace, and defense in order to accelerate adaptation for changes in market and demand conditions, and to support economic growth and development. In these complex and competitive environments, analyzing manufacturing industry and R&D activities by researchers became more strategic from the different perspectives more than ever.

Kim (2000) investigated R&D activities of SMEs in ICT sector in South Korea and showed that SMEs are more active than large firms in terms of R&D activities, in other words contradiction of Schumpeter's Hypothesis.

Albaladejo and Romijn (2000) investigated the determinants of innovation capability in small and medium firms in the United Kingdom for the years 1998-1999 and emphasized that while internal inputs R&D expenditure, investment in staff training and R&D, number of scientists, and engineers or R&D staff employed are the most observable ones, and such as technical education level and experience of owner of the large firm and R&D institutions, technical skill of labor, and so on are the other internal factors, external factors are public financial support for R&D, and interaction between R&D and training institutions, and so on. According to them, innovation capability of a firm is expanded by several ways such as education (internal learning and in-house staff training), investment (formal R&D investments), informal experimentation, debugging, adaptation (to products, processes, and organization), and so on.

Cumming and Macintosh (2000) investigated 56 Canadian firms in biotechnology industry to reveal determinants of R&D expenditure such as patent protection and strategic alliances that ease R&D expenditure. They showed that firms engaged in R&D and firms with high debt-equity ratios allocate a lower proportion of their expenditures to R&D than early-stage firms.

Fritsch and Meschede (2001) analyzed the relationship between R&D expenditure and firm size with 1800 German enterprises in manufacturing sector for the years 1993-1995 and showed that there is a positive relationship between R&D expenditure and firm size. According to their results, the share of firms engaged in product innovation is higher than the share of firms engaged in process innovation while the share of expenditures on product innovation in *total R&D expenditure* (on the average, especially in small firms) is higher than average expenditure on process innovation.

Hall (2002) emphasized the importance of making up a deficiency in financial sources that is a lack of funding for R&D investment (called as funding gap). As a

solution, she proposed that venture capital is needed to close the gap as well as governmental seed capital and subsidy programs.

Subodh (2002) analyzed Indian firms in two sectors such as drugs and pharmaceuticals, and electronic between the years of 1992-1997 to reveal relationship between market structure (firm size and market concentration) and innovation activity by using probit and tobit analyses. According to the results, there are inter-industry differences, and no evidence for powerful and larger firms in the market that engage in more innovative activities. He emphasized that testing the hypothesis in different industries separately is the best method to reveal the inter-industry differences.

Smolny (2003) investigated 1982 West-German manufacturing firms to research determinants of innovation behavior and investment for the years between 1980 and 1992. According to this firm-level panel analysis, market power, export, and demand structure of the firm support innovation activity and there is a positive relationship between firm size and innovation.

Lee (2004) analyzed 749 Malaysian manufacturing firms to search the determinants of the propensity to innovate by using logit model. He used high tech classification for manufacturing industries (such as high tech, medium-high tech, medium-low tech, and low tech) and hypothesized that firms in high-tech industries are more innovative than firms in low tech industries, but there is a contradiction. Only firms in high-medium tech industries are less innovative than firms in low tech industries. In this study, age of firm, ownership, firm size (by the number of total employees), export, and Herfindahl-Hirschman Index (*HHI*) (as a measure of market concentration) were used to test their effects on innovation. According to the results, explanatory variables such as firm size (positive sign), export (negative sign), and market concentration (positive sign) are statistically significant at five percent level.

Bhattacharya and Bloch (2004) analyzed 1213 Australian manufacturing firms for the years between 1997-1998 to reveal determinants of innovation by using probit model and by classifying industries as high tech and low tech. According to results, there are positive relationship between innovation and some determinants such as firm size (sales), market structure (CR4), trade shares (exports/total sales, imports/total

sales), and R&D intensity (R&D expenditure/sales) but there are differences between high tech and low-tech industries.

Avermaete, Viaene, and Morgan, et.al. (2004) analyzed 177 EU manufacturing small firms in the food and drink manufacturing industry by using multinomial logistic models to reveal the determinants of product and process innovation such as entrepreneurial characteristics (age, education level, experience), labor skills (number of qualified technical personnel, number of managerial and professional personnel, percentage of technical personnel, percentage of managerial and professional personnel), investment in know-how (training costs, marketing costs), reliance on consultancy (administrative, marketing, and technical), and sources of innovation (similar firms, suppliers, customers, contract R&D). According to their results, firms with a higher number and proportion of qualified technical personnel are more innovative than firms with a lesser number of them while only the number of managerial and professional personnel has a positive relationship with innovation. The other result is that there is a positive relationship between investment in know-how and innovation. Moreover, firms' R&D efforts are positively related to the firms' collaboration with their customers and research institutes.

Leiponen (2005) analyzed 159 Finnish manufacturing firms between the years of 1990-1996 to test the hypothesis that high technical skills of labor are complementary with innovative activities such as R&D collaboration and product or process innovation. She suggested investment in skills of labor to increase firms' benefit from innovation and firms' absorptive capacity as mentioned by Cohen and Levinthal (1989, 1990), Romer (1993).

Shefer and Frenkel (2005) underlined the importance of investment in R&D and having highly skilled labor for a firm. They analyzed 209 manufacturing firms in Israel to show the relationship between R&D expenditure and firm's characteristics (such as firm size, type of industrial branch, ownership, and location). According to this study, there is a negative relationship between firm size and R&D activities, except plastics and metals industries. Additionally, R&D activities are affected by other variables such as industrial branch and location of firm.

Lehtoranta (2007) analyzed the relationship between innovation activities and its determinants such as R&D and patenting activities, highly skilled labor, and acquisition. According to the study, there is evidence that those determinants affect innovative activities and commercialization.

Vaona and Pianta (2008) analyzed 22 EU manufacturing sectors for eight European countries (Austria, France, Italy, Norway, the Netherlands, Portugal, Sweden, and the United Kingdom) with industry-level data to reveal the differences between small, medium-sized, and large firms regarding their performance of innovative activities in terms of product and process innovation. They showed evidence of differences in terms of determinants of both innovations and firm size.

Radas and Božić (2009) emphasized the lack of studies on innovation of SMEs for developing economies. They analyzed 448 small and medium-sized firms in Croatia by using logit model to reveal the determinants of product and process innovation such as external factors (innovation subsidies by municipality, government, and collaboration), internal factors related firm characteristics (age of firm, share of highly educated employee, share of full-time equivalent employees engaged in intramural R&D), and internal factors related strategy, marketing, management, and organizational structure. According to the study, the share of highly educated employees has a positive impact on product innovation, changes in corporate strategies supports likelihood of radical innovation, and there is a positive relationship between market scope and innovativeness.

Hall, Lotti, and Mairesse (2009) analyzed Italian small and medium-sized firms for the periods between 1995-2003. According to the study, firm size and R&D intensity have positive effect on the probability of process and product innovation.

Raymond and St-Pierre (2010) analyzed 205 Canadian manufacturing SMEs by technological intensity (high-tech, medium-high, medium-low, low-tech) to reveal the effect of R&D by separating innovation (R&D from process R&D, process R&D from process innovation, and process innovation from product innovation). According to the study, the effect of R&D on product innovation is mediated by process

innovation and there is a significant interrelationship among R&D, process innovation, and product innovation.

Ganotakis and Love (2011) investigated determinants of innovation and the relationship among R&D, innovation, and export for some industries (pharmaceutical, computer, aerospace, telecommunications, software etc.) for the United Kingdom by separating R&D expenditure into two parts such as internal and external R&D [like Cohen and Levinthal (1989), Audretsch, Menkveld, and Thurik (1996)]. According to the study, internal R&D fosters innovation. In the study, there were some criteria to identify the R&D intensity such as R&D expenditure over total sales or R&D expenditure over value-added, additionally the number of researchers (scientists and engineers) in R&D activities over total employment.

Nieto and Rodriguez (2011) investigated the impacts of R&D offshoring (captive offshoring and offshore outsourcing) on product and process innovation in Spain for the period 2004-2007. The study indicated some valuable results such as: offshoring R&D expenditure positively influences firm's innovation performance, and this effect is more on product innovation than process innovation; and captive offshoring is more effective than offshore outsourcing.

Majumdar (2011) analyzed more than ten thousand Indian manufacturing firms to investigate the relationship between R&D expenditure and firm size for the period between 2000-2006. According to the study, larger firm size increases the probability of R&D expenditure.

Revilla and Fernández (2012) analyzed Spanish manufacturing firms to investigate the relationship between firm size and R&D. According to the study, innovation performance of firms by firm size changes with respect to technological regimes (appropriability, technological opportunity, and knowledge cumulativeness), like Cohen and Levinthal (1990) and Kumar and Saqib (1996).

Zemplerova and Hromadkova (2012) analyzed 2071 Czech firms for the period between 2004-2006. According to the study, there is a negative relationship between public subsidies to private R&D activities and innovation, and a negative relationship between firm size and innovation.

Clausen, Korneliussen, and Madsen (2013) analyzed 1199 Norwegian firms that engaged in R&D to reveal the relationship between product innovation and four innovation modes (firms' approach to product innovation) such as open exploration, closed exploration, open exploitation, and closed exploitation. They emphasized that market and technological resources of a firm affect its product innovation performance and showed that the better of both resources more likelihood of introducing new product innovation.

Esteve-Perez and Rodriguez (2013) analyzed 1016 Spanish manufacturing firms for the period between 1990-2006 to investigate the relationship between R&D and export in terms of product and process innovation. According to the study, there is a two-way positive relationship between export and R&D activities.

Carvalho, Costa, and Caiado (2013) analyzed 4504 Portuguese manufacturing and services firms for the years between 2002-2004 with a logit model to investigate the determinants of their innovation behavior in terms of four types of innovation such as product, process, organizational, and marketing. They used many variables to predict innovation such as internal R&D, external R&D, acquisition of tangible (machinery, equipment, software) and intangible (other external knowledge) inputs, training, market introduction of innovation, and other procedures. They focused on the main idea that how those variables affect the odds of innovation. According to the study, there is a positive relationship between internal R&D and innovation. External R&D is not statistically significant for product, process, and marketing innovations.

Sanchez-Sellero et al. (2015) analyzed 1872 Spanish manufacturing firms to investigate the relationship between innovation and productivity. According to the study, R&D activities are important in terms of improvement of firms' productivity. They showed that the effects of external R&D activities are more than the effects of internal R&D activities. They emphasized that product and process innovation improve capability of firms to sustain their activities in terms of new knowledge production and its application in the activities that increase productivity. They also indicated that if firms carry on their R&D activities in collaboration with universities, technology centers (technopark, technopole, technology park, science park, and so on)

and if they employ new graduates who studied in science, engineering, or technology, they give an outstanding performance with higher productivity.

Song and Oh (2015) analyzed 2904 Korean firms in energy intensive industry with probit model to investigate the effects of R&D activities on product and process innovation. They used many determinants of innovation such as market structure (CR3), R&D intensity (R&D expenditure/sales), R&D personnel ratio (the number of R&D personnel/the number of total employee), firm size (by sales), export ratio (export/sales), and advertising intensity (advertising expenditure/sales). They showed that the number of R&D personnel influences both product and process innovations, but R&D expenditure influences only process innovation. On the contrary, in less energy-intensive industries, the number of R&D personnel and R&D expenditure have a positive effect on product and process innovation. Shortly, when industry is separated or grouped, the effects of R&D activity variables on product and process innovation differentiate.

Lee, Zhou, and Hsu (2015) analyzed 6695 firms in the US for the period between 1976-2005 to reveal the relationship between process and product innovation performance and inventory *turnover* performance of the firm. According to the study, there is a positive effect between innovative activities and operational performance. They showed that product innovation catalyzed the interest of customer therefore caused demand growth, and process innovation caused more sales with the improvement of customer shopping or ordering experience, and investment in process innovation is more effective than investment in product innovation to have a better inventory *turnover* performance in the long run.

Vokoun (2016) analyzed Czech manufacturing firms for the period between 2006-2010 to reveal the characteristics of process innovators from the sustainable regional development perspective. According to the study, continuous process innovation is important for sustainable urban development and large firms with a high adaptation ability to changes have a critical role for it. Moreover, these firms have a higher likelihood of engaging in continuous process innovation. They emphasized that essential boosts for regional development can be acquired by public policies about

technology hubs and networks, instead of public policies about grants and subsidies for innovation projects.

Baumann and Kritikos (2016) analyzed German manufacturing firms to reveal the relationship among R&D, innovation, and productivity by regarding difference between micro firms and larger firms. According to the study, there is a negative correlation between firm size and R&D intensity (perhaps because of higher start-up cost), and micro and larger firms are similar in terms of transforming knowledge into productivity. They emphasized the importance of R&D that causes to increase the likelihood of introducing an innovation and have bigger effect on product innovation than process, and the importance of high skilled employees and tangible investments (specifically, machinery and equipment) in terms of increase in the likelihood of introducing an innovation.

Adeyeye et al. (2016) analyzed Nigerian manufacturing firms by four types of innovation (product, process, organizational, and marketing) to reveal the relationship between innovation activities and R&D expenditure. According to the study, internal R&D one of the significant determinants of all types of innovation and there is a positive relationship between tangible investments (specifically, machinery and equipment) and likelihood of introducing product innovation to the market.

Soetevent and Bruzikas (2018) investigated the effect of process innovation in fuel retailing sector (fuel stations) in the Netherlands after transition from traditional technology to automated one. They showed that this process innovation caused a reduction in the price by 1.7% to 3.2%, and this innovation affected prices at other stations within 2 km of an automated one (a reduction by 0.2%, on average,).

Seenaiah and Rath (2018) analyzed 190 Indian manufacturing firms to reveal the determinants of innovation for Indian manufacturing sector in cities of Bengaluru and Hyderabad by using panel probit model. According to the study, there is a positive relationship between R&D expenditure and innovation, and between export and innovation. They suggested some policies such as R&D subsidy policy and R&D incentive projects to boost innovation in India.

Un and Rodriguez (2018) investigated the effect of R&D outsourcing (external R&D) on product innovation and separated R&D outsourcing into two parts such as ‘learning from R&D outsourcing’³⁰ and ‘from learning by R&D outsourcing’³¹. They also separated R&D outsourcing into two parts such as domestic (external-domestic) and foreign (external-foreign) to check a liability of foreignness³². According to the study, there is an inverted U-shaped relationship between external R&D and the number of product innovation, between interaction of external and internal R&D and the number of product innovation. Moreover, *external-domestic R&D expenditure* has a greater effect on product innovation than *external-foreign R&D expenditure* has.

1.5. Studies on R&D and Innovation in Türkiye

Dosi (1988) emphasized that most of studies concerned the relationship between R&D expenditure (resources) and rate of introducing product and process innovations. However, studies on R&D activities and innovation in Türkiye mostly focused on growth and productivity, mostly related to macroeconomics perspectives. Moreover, there are studies on Turkish manufacturing industry but shallowly. They are mostly focused on the manufacturing industry as a whole. There are many studies that focused on several topics such as:

- productivity (Taymaz and Saatçi, 1997; Önder et. al., 2003; Özler and Yılmaz, 2009; Alvan and Ghosh, 2010; Falcıoğlu, 2011; Attar, 2017; Işık and Taşgın, 2017; Doğan, 2017),
- innovation and R&D (Yörükoğlu, 2000; Pamukçu and Boer, 2000; Uzun, 2001; Özçelik and Taymaz, 2008; Pamukçu and Utku-İsmihan, 2009; Taymaz and Üçdoğruk, 2009; Özdemir Güngör and Gözlü, 2012; Ayaydın and Karaaslan, 2014; Ulusoy et. al., 2015; Öztürk and Zeren, 2015;

³⁰ R&D Outsourcing will help directly to the firms through improvements in its ability to innovate in terms of in product innovation.

³¹ R&D outsourcing will help indirectly to the firm for product innovation through the integration of internal R&D and R&D outsourcing.

³² Analysis for whether foreign R&D outsourcing has a lower or a greater effect on product innovation than domestic.

Limanlı, 2015; Savrul and İncekara, 2015; Karabulut, 2015; Burmaoğlu and Şeşen, 2017),

- growth and R&D (Ülkü, 2007; Bayarçelik and Taşel, 2012; Akçalı and Şişmanoğlu, 2015; Tuna et. al., 2015), and
- productivity and R&D (Ülkü and Pamukçu, 2015; Doğan, 2017; Karaca, 2018).

R&D activities and innovativeness (process and product innovation) is one of the much-discussed topics in the world. Firms are crucial actors to analyze in terms of understanding innovation and its determinants. There are some studies that focused on these innovations and factors that affect them in the world [most of the studies as mentioned before such as Martinez-Ros (1999) in Spain, Raymond and St-Pierre (2010) in Canada Nieto and Rodriguez (2011) in Spain, Song and Oh (2015) in Korea, Adeyeye et al. (2016) in Nigeria, Un and Rodriguez (2018)], and a few studies in Türkiye (Taymaz, 1997; Pamukçu and Boer De, 2000; Uzun, 2001; Özdemir-Güngör & Gözlü , 2012; Attar, 2017; Burmaoğlu ve Şeşen, 2017; Doğan, 2017; Öztürk, 2018-2019).

In Türkiye, a project that was funded by the World Bank, TURKSTAT, and several banks was carried out to collect firm-level data regularly and to analyze it. Taymaz (1997) took part in this project that was a milestone in firm-level, sector-level, and country level analyses of Turkish manufacturing industry. In the next years, studies that focused on country-level and firm-level analyses have started to increase in Türkiye.

In Turkish manufacturing industry case, Pamukçu and Boer De (2000) analyzed 1108 Turkish manufacturing firms with bivariate logit model for the years between 1989-1993 (with data in 1994 provided by the Technology Development Foundation of Türkiye) to investigate the relationship between probability of introducing an innovation and its determinants (by regarding four types³³ of innovation

³³ Four types of innovation are product innovation (improvement and new product) and process innovation (improvement and new process).

as a whole) in Turkish manufacturing industry such as international technology transfers, skill level of labor, competition on the international markets, international technology transfer, and price level. According to the study, these determinants have a positive effect on the probability of innovation.

Uzun (2001) analyzed 2100 Turkish manufacturing firms with a correlation analysis to understand insights of technological innovation and R&D activities in Turkish manufacturing industry for the years between 1995-1997, by using national-wide technological innovation survey (conducted by SIS³⁴ and TÜBİTAK³⁵). He stated that most of innovation activities are conducted by large firms, and the source of more than half of the total sales is technologically new and improved products (product innovation) in most of Turkish manufacturing sectors. According to the study, there are weak correlations between innovation and its determinants such as R&D expenditure, sales of new products, and firm size.

Özdemir-Güngör and Gözlü (2012) analyzed 1152 Turkish firms (860 in manufacturing, 165 in service) by using World Bank 2009 data³⁶ to reveal the relationship between innovation (product and process) and its determinants such as internal factors (R&D investment, licensed technology, number of employees, training, education level, type of establishment, and manager experience) and external factors (pressure, sales profile, and suppliers' profile). According to the study, Turkish firms tend to innovate more in process innovations, the number of process innovation is more in manufacturing industry than service, innovative firms tend to invest more in their capability of innovativeness, firms engaged in product innovation activities are also mostly engaged in process innovation, and significant internal factors are R&D activities, licensed technology, formal training, and manager experience.

Burmaoğlu and Şeşen (2017) analyzed 5863 Turkish firms in industrial sectors (with three model) and service sectors (with three model) by using CIS data conducted by TURKSTAT in 2008 to investigate the determinants of product innovation and

³⁴ Now, its name is TURKSTAT.

³⁵ the Scientific and Technological Council of Türkiye.

³⁶ Business Environment and Enterprise Performance Survey by the World Bank in 2009, and the data was collected in 2008.

service innovation such as R&D intensity³⁷ (internal R&D and external R&D), market diversity, networking factor, financial support, revenue per unit employee, inner information focus, openness for information sources, endorsement (income/employee), number of employee (its log), domestic and foreign investment ratios. According to the study, the number of firms that engaged in product innovation is higher in the manufacturing industry and it is same as for process innovation. For product innovation, financial support (necessary determinant), intra-organizational sources of information (that increase capacity of innovativeness), market diversity, and dependency of firm on external sources of information (capability of performing innovation) have a positive contribution. The number of employees, endorsement, networking factor have a negative effect. Domestic investment ratio has a positive effect on product innovation but an increase in foreign investment ratio has negative. According to them, aims of foreign investment ratio in Turkish firms are market creation oriented for foreign firm more than product innovation capacity enhancing oriented.

Doğan (2017) analyzed Turkish manufacturing sector for the years between 2003-2012 to reveal complementarity between decision of firms to invest in R&D and to export, the effect of complementarity between firms' R&D and export activities on productivity, and the effect of process and product innovation on future productivity of firms. In the last part of her dissertation can be separated into two subparts such as productivity perspective and the probability perspective. 610 Turkish manufacturing firms were analyzed related to process and product innovations for the years between 2008-2012 (CIS data in 2010 and in 2012 were used). She used some variables such as production value from AISS data, the number of R&D personnel and R&D expenditure from RDAS, firm age from BRF³⁸ data, and export indicators from FTS³⁹ data. In the first subpart, the effects of both innovations on productivity were analyzed.

³⁷ R&D intensity (by employee) was calculated as dividing each R&D expenditure by the number of employees such as intra-organizational R&D expenditure, expenditure of R&D services purchased externally by the firm, expenditure for machinery-equipment-software procurement, and expenditure for patent and know how purchase.

³⁸ Annual Business Registers Framework Micro Data Set.

³⁹ Foreign Trade Statistics Micro Data Set.

From the sectoral differences perspective, she provided data only for the share of innovative firms in product and process innovation by manufacturing sectors to compare the two periods of R&D activities (CIS data in 2010 and in 2012). In the second subpart, the effect of R&D intensity on productivity through product and process innovation were analyzed with many variables such as R&D intensity (R&D expenditure/total capital stock), average capital stock (proxy for firm size), average fixed investment intensity (fixed investment expenditure/total capital stock), firm age, the share of foreign capital (dummy), and group (dummy). According to the analysis in the second subpart, there are many results such as: i) R&D intensity does not affect product innovation but process innovation positively. ii) Interaction between R&D intensity and fixed investment intensity does affect product innovation positively while interaction between R&D intensity and investment intensity does affect it negatively. iii) There is a positive relationship between the group and both innovations. iv) The effect of product innovation is more on productivity than the effect of process innovation on it.

Öztürk (2019) analyzed innovation activities⁴⁰ and the role of innovative entrepreneur in Türkiye with logit and multinomial logit to reveal the determinants of innovation activities. She generated three different data sets such as CIS data for model 1 (cross sectional, and 3337 firms, 2012), data by merging CIS and RDAS for model 2 (cross sectional, 927 firms, 2014), and data by merging BRF and CIS (panel, 4921 firms, 2004-2014) for model 3. According to analysis, there are some results such as: i) If a firm have an internal R&D department, its probability of innovation is more than firms without the department, and R&D department support increase in the probability of organization and marketing innovation by comparison the probability of product innovation, ii) If the share of educated employee in total employee in the firm is more than average, its probability of innovation is more than other firms' probability, and its probability of process and marketing innovations is less than the probability of product innovation, and the probability of organizational innovation is more than the probability of product innovation, iii) If firm has Ph.D. level personnel

⁴⁰ Product innovation, process innovation, marketing innovation, organizational innovation, and multiple innovative activities.

its probability of product innovation is more by comparison other innovation types. iv) If the share of R&D expenditure in total expenditure is more than average for a firm, its probability of product innovation is more than the probability of organizational innovation. v) There is negative relationship between the probability of innovation and production for only Turkish market, and between the probability of innovation and availability of foreign capital. vi) If the import ratio is more than average for a firm the probability of innovation is less than other firms, and it is vice versa for export ratio.

Taymaz and Saatçi (1997) showed that there are differences among sectors in terms of technological change ratios and productivity, and they emphasized that differences among industries must be taken account in studies. However, it is seen that some studies did not take account this suggestion (Pamukçu and Boer, 2000; Uzun, 2001; Özçelik and Taymaz, 2008; Bayarçelik and Taşel, 2012; Özdemir Güngör and Gözlü, 2012; Ayaydın and Karaaslan, 2014; Karabulut, 2015; Burmaoğlu and Şeşen, 2017). In some studies, industries are analyzed with respect to main activity (NACE Rev. 2, | 2 digit) but there are no sectoral comments as a result (Doğan, 2017; Karaca, 2018). Some other studies analyzed the industry by separating and classifying it (Taymaz and Üçdoğruk, 2009; Pamukçu and Utku-İsmihan, 2009; Ayaydın and Karaaslan, 2014; Ulusoy et. al., 2015). Pamukçu and Boer De (2000) did not separate innovations for the analysis but analyzed it as a whole. Doğan (2017) focused mainly on productivity.

1.6. Product and Process Innovation

Product and process innovations are two significant sources of knowledge accumulation (Aghion and Howitt, 1992) and two of Schumpeter's distinction of innovations (Kennedy and Thirlwall, 1972; Feeny and Rogers, 2003). These innovations that are mostly introduced by firms in the economy require great expenditures on R&D activities (e.g., researchers, education, R&D infrastructures) because R&D activities may cause new or improved products and processes (Hall, 2008).

Frascati Manual 2015 (last revision) defines R&D as “research and experimental development” that “comprise creative and systematic work undertaken in order to

increase the stock of knowledge – including knowledge of humankind, culture and society – and to devise new applications of available knowledge” (OECD, 2015).

A product innovation is defined as “a new or improved good or service that differs significantly from the firm’s previous goods or services and that has been introduced on the market”, and a business process innovation is defined as “a new or improved business process for one or more business functions that differs significantly from the firm’s previous business processes and that has been brought into use in the firm” (OECD & EUROSTAT, 2018). In the light of Oslo Manual and Community Innovation Survey (CIS -implemented by EUROSTAT), TURKSTAT conducts this innovation survey every two years for a three-year period.

It is clearly seen that research on R&D and innovation is increasing decade by decade. Most of these studies focused on manufacturing industry in a country to support determination process of R&D, technology, and innovation policies. In this dissertation, Turkish manufacturing firms that engaged in R&D are analyzed for the years between 2009-2016 to reveal the relationships between innovation (product and process) and its determinants (such as R&D expenditure, R&D intensity, *R&D personnel intensity*, *turnover*, market structure, number of high educated R&D personnel, *industrial production index by manufacturing industry sectors*) from the five perspectives that are explained in the introduction of the dissertation.

In the next chapter, science and technology (S&T) and R&D about Türkiye, and of Turkish Five-Year Development Plans (5YDPs) are presented generally. After that, detailed R&D statistics in Türkiye were elaborated with numerous figures.

CHAPTER TWO

SCIENCE AND TECHNOLOGY, R&D ACTIVITIES, AND EDUCATION OF TÜRKİYE

In chapter I, the theoretical framework of the dissertation was provided in terms of R&D and innovation literature by focusing on R&D, technological change, research, firm characteristics, product and process innovation and so on.

In this chapter, a bird's-eye view of science and technology (S&T) and R&D in Türkiye, and of Turkish Five-Year Development Plans (5YDPs) are presented. After that, detailed R&D statistics in Türkiye were elaborated and supported by numerous figures. This part will be as a brief history of R&D and S&T activities in Türkiye.

2.1. S&T, R&D Activities, and Education of Türkiye

S&T and R&D are key factors to improve level of technology in a country and to boost economic growth and development. These key factors are related to education issues. Education is significant factor that increases skill and quality of workers and researchers who are strategic actors of S&T and R&D. If a country cannot educate its human capital as it must be in that period, it may not converge to more developed country. This absence may cause an increase in the gap between developing and developed countries. There is a connection between developments in education and developments of workers' quality (Kepenek, 2020). If there is highly skilled and quality workers, a country can increase its technological level, its ability of technological adaptation and technology adoption. All these factors, S&T-R&D-education must be centered on economic growth and development policies in a country. To understand the developments in the 20th century, it is important to briefly review the last century of the Ottoman Empire.

The Industrial Revolution in the 18th century has played an important role in development of production technology and product variety. Countries that upgraded themselves for the industrial age grew and developed more. Upgraded production

technology must be supported with coherent education system that is necessary for workers and researchers. For instance, Imperial School of Naval Engineering (Mühendishane-i Bahr-i Hümayûn) was established in 1773 in the Ottoman Empire, with the support of Baron de Tot (French military officer), after its defeat in Battle of Chesme. This defeat showed that ship technology must be upgraded, and shipbuilding activities must be developed. In the 19th century, in the Empire, modernization efforts continued in terms of technology, administration, economy, and society. However, the Empire had its another defeat in the Battle of Navarino (Navarin) in 1827. In the same year, steamships started to be used in the country (Tızlak, 2000; Beşirli, 2004). But the number of crew is not enough for these steam ships and naval ships. More clearly, captains and engineers came from USA and England in the 19th century mostly (Beşirli, 2004). According to Gençoğlu (2015), these developments showed that there is knowledge and technology transfer from those countries to the Ottoman Navy. The Empire attempted to industrialization processes to meet the needs for the military, the navy, and the state by establishing factories with latest machines that were imported from the Europe by administrators but could not be used after the 1850s (Pamuk, 2016). The imported machines were kinds of technology transfer for industrialization but making use of them were limited because of lack of skilled labor and economical and political concerns and developments. These examples also showed that education system must be upgraded and supported to increase the number of highly skilled and quality workers, engineers, and researchers, and to improve the ability of technology adoption and technological adaptation.

In the 19th century, in the Ottoman Empire, there are many developments such as: attempts to build an education system and a university, which is Darülfünun; first S&T societies were established; many developments in mathematics, physics, astronomy, chemistry, zoology, botany, geology, geography, and medical were seen such as translation studies and establishment of hospital, institutes, observatory, and so on (Türkcan, 2009). However, there were many problems for the education system such as: there was three-dimensional education system (schools of minorities and foreigners, modern Ottoman schools, and traditional schools based on Islamic

education); and literacy rate was approximately 10% during the last years of the Empire (Kepenek, 2020).

The education system was not based on a common scientific approach in Ottoman Empire while it was scientific, rational, and modern in the Republic of Türkiye to meet the demand for skilled labor force by increasing the number of students in schools (Kepenek, 2020). There were some developments in the 1920s and the 1930s such as: the law on unification of education in 1924 was promulgated in Türkiye; and S&T reform in İstanbul University was seen in 1933. In the 1940s, some developments in higher education were seen as establishing and modernizing universities such as Istanbul Technical (1944), Ankara (1946) (Ayhan, 2002). There were significant developments in education system between 1935 and 1945 to meet demand for skilled labor force and to increase the literacy rate such as: increase in the number of primary school (rural) and students more than 100%; six times increase in the number of students in vocational and technical schools; approximately 165% increase in the number of students in high schools and universities (Kepenek, 2020).

In 1950, Türkiye had no more than 90 high schools with almost twenty million population (Pamuk, 2016). However, during the 1950s, many universities were founded such as Ege (1955), Karadeniz Technical (1955), Middle East Technical (1956), Atatürk (1957), and so on. The literacy rate was approximately 30% in 1945, 33% in 1950, 40% in 1960, 68% in 1980, and 94% in 2010 (Pamuk, 2016; Kepenek, 2020). According to Pamuk (2016), there was no successful performance in education in terms of its content, quality, and training capability when compared with other low-income countries. During the 1950s, thanks to the developments in education, economy and public administration did not have problem for skilled labor force but modern education and unification of education system were forgotten, and quality of education could not be changed (Kepenek, 2020). According to Ayhan (2002), S&T policies were so weak during the period between 1950 and 1960.

In the 1960s, in the shadow of import-substitution policy and mixed economy model, Türkiye focused on the domestic market-oriented industrialization strategy within the framework of 5YDPs. The period between the years 1960 and 1980

represents the period of planned development and was the period that winds of science policy started to blow among countries after WWII. However, there was no broad S&T policies and targets for researchers, and research fields could not be met between 1960 and 1980. In the 1960s, only Hacettepe University was founded while in the 1970s, many universities were founded such as Anadolu, Uludağ, Erciyes, and so on (Türkcan, 2009).

During the 1980s, Turkish Science Policy 1983-2000 was published and included first long-term S&T policies framework clearly but could not be implemented clearly because of the 24 January Decisions and the 1980 Military Coup.

After the Disintegration of the Soviet Union and the Eastern Bloc, in the shadow of globalization, Türkiye did not have some main parameters sufficiently such as accumulation of technology and *R&D personnel intensity* (Ayhan, 2002). Turkish S&T Policy 1993-2003 was published but implement of S&T policies was delayed because of 1994 Turkish Economic Crisis and political and economic instabilities. Pamuk (2016) emphasized that investments in infrastructure and education system, reaching higher levels of S&T, and meeting demand for high skilled and capabilities of labor force were required to solve many problems such as low-level investment rates, low growth rate of manufacture goods production, and lack of diversifying.

The period between 1980 and 2000, industrialization in Türkiye was based on import of technology because of the lack of capital-technology-skilled labor force instead of high-tech industries' technology, in other words Türkiye maintained its industrial production with labor-intensive technology and R&D was insufficient even though the importance of R&D and R&D expenditure was emphasized many times (Ayhan, 2002). Doğruel and Doğruel (2019) emphasized that industrialization became primarily policy in the period between 1930 and 1980, but after 1980 it was not, in other words Türkiye followed a deindustrialization route especially in the 2000s by starting in the 1990s, and average technology level of Turkish manufacturing industry decreased after the 2008 Crisis because of continuing deindustrialization processes since the mid of the 1990s.

According to Ayhan (2002), production of science and production of technology could not be linked together in Türkiye. Because R&D and education are key factors in production of S&T. The absence of these three factors leads to disconnection / weak connection between production of science and technology so weak innovativeness. Türkcan (2013) also stated that Türkiye did not try generating a connection among science, technology, and industry, in addition, did not accept strong connection between them. According to Emre Alkin, education is the most significant field to plan for economic development, and moreover know-how and creativity are still one of the most serious problems of Türkiye (Alpay and Alkin, 2020).

A country must strength its education infrastructure and R&D infrastructure by creating a link between them and industry, with efficient economic, S&T, and R&D policies. In this environment, a country can increase its innovativeness by increasing the number of highly skilled and quality workers, engineers, and researchers who can work in modern R&D laboratories and in industries with high-tech.

Development of S&T and R&D policies in Türkiye can be viewed by the help of 5YDPs to understand the link among S&T, R&D, industry, and education. In the next, this topic will be examined.

2.1.1. S&T, R&D Activities, and Education in The Five-Year Development Plans (5YDPs) of Türkiye

In the 1960s, Türkiye started to implement 5YDPs that were based on many preparations such as establishment of State Planning Organization (SPO)⁴¹ and determination of personnel, preparing regulations and so on. These 5YDPs focused on upgrading of Türkiye in the long term for Turkish economic growth and development. S&T and R&D were two of significant topics in the 5YDPs.

Türkiye has prepared eleven 5YDPs until 2023. All 5YDPs were viewed here in terms of S&T, R&D, and industry.

⁴¹ Ayhan Çilingiroğlu and Attila Karaosmanoğlu were two of key persons during the establishment of SPO in Türkiye (DPT in Turkish) and for the preparation of first plans, who worked together with Jan Tinbergen [for details, look at Türkcan (2010)].

- I. 5YDP: The first 5YDP comprises the period between 1962 and 1967. In this plan, there are some aims and developments in terms of education, S&T, and R&D (SPO, 1963) such as: increasing the number of academicians in the higher education sector by supporting them to study abroad for master and doctoral research (target: 3000, actual: 500) to meet the demand for high educated researcher and assistant personnel (totally 3330); TÜBİTAK was founded in 1963 to advance S&T, support Turkish researchers, and to promote, develop, organize, conduct, and coordinate R&D activities (TÜBİTAK, n.d.); revising and developing the education of chemical engineering in universities to meet the demand for skilled labor in modern chemical industry because of insufficient conditions; establishing libraries to ease finding basic publications; translating well-known publications to increase research level; researches must focus on concerns about fields related with development to find solutions for Türkiye. Moreover, in 1965, the National Productivity Center was founded to provide training that enhances productivity and technology.

In this period, the share of R&D expenditure in GDP was 0.4% (some countries 0.6%) and the share of R&D personnel in population was 0.012% in 1964 (some countries 0.6%) (SPO, 1968). According to Arap and Erat (2018), the establishment of TÜBİTAK was the most significant realized goal in this plan. Many aims in the first plan could not be realized such as: the efforts for meeting the demand for high educated researcher and assistant personnel resulted in failure, and this was a big obstacle for opening universities and higher education institutes; Economic and Social Research Institute could not be established; the research policy about sector related researches that were compatible with the economic development could not be implemented because research was generally basic research oriented (SPO, 1968). It is highlighted that the importance of research was could not understand in Türkiye (SPO, 1963). According to Ayhan (2002), there is a lack of policy to improve technology transfer, education/training, and R&D activities.

- II. 5YDP: The second 5YDP comprises the period between 1968 and 1972. In this plan, there are some aims and developments in terms of education, S&T, and R&D (SPO, 1968) such as: increasing the number of researchers from 3500 to 5000; supporting people to study abroad for master and doctoral research (target:3000); establishing an institution that is responsible for providing the cooperation among universities; starting the evening education to meet the demand for educated labor force for sectors; establishing Industrial Research Institute under the TÜBİTAK, and Turkish Economic and Social Research Institution; increasing the share of R&D expenditure in GDP from 0.4% to 0.6%; developing necessary libraries and laboratories for researchers without making discrimination; encouraging foreign researchers to work in Türkiye; providing cooperation for science and research with developed and developing countries; removing limits for revenue from research to support research and researchers; promoting private sector to research.

According to Ayhan (2002), there was an absence of S&T policies that were based on real and strong fundamentals because production plants that were established with financial supports of the western countries and Russia after 1965 could not produce technological innovation such as product and process innovation because the machines were based on old technology.

The first and second plan were failed in terms of the aim of preventing brain drain⁴², and in terms of the aim of supporting people to study abroad for graduate research (target was 6000 students) (SPO, 1973). However, only 1181 students were supported to study abroad for graduate education in Türkiye, the ratio of the number of graduate students to total number of students was increased from 0.6% in 1961 to 1.8% in 1970, and the number of technical labor force could not be increased until the 1970s, except labor force in social sciences etc. (SPO, 1973).

⁴² According to SPO (1973), every year, on average,, 375 Turkish researchers left the country during the period between 1962 and 1967 (51.5% of them in medical, 40% of them in engineering, 5.5% of them in natural sciences, and 3% of them in social sciences).

In terms of qualities of industrialization and consumer durable goods production, there were no details about what production technology of the manufacturing industry was⁴³ in the first (1963-67) and the second (1968-72) 5YDPs (Kepenek, 2020).

- III. 5YDP: The third 5YDP comprises the period between 1973 and 1977. In this plan, there are some aims and developments in terms of education, S&T, and R&D (SPO, 1973) such as: prioritizing applied research; educating labor force (scientific, technical, and research) that will do applied research for adaptation of transferred technology by enhancing their capability and ability of transferred technology usage with the creation of two channel system with universities and high schools; developing a subsidy system for publication to spread research idea and to promote scientific events.

In third plan, it is emphasized that determining of the critical sectors for technology by estimating technological developments in the long run is significant under the export-oriented industrialization strategy, such sectors as studies on process design and numerical control machines (SPO, 1973). In the public sector, the share of R&D expenditure to GDP in was 0.41% in 1964, 0.36% in 1969, and 0.35% in 1970 (SPO, 1973).

The production of intermediate and investment goods were privileged in manufacturing industry (as a driving) in the third (1973-77) 5YDP (Kepenek, 2020). Many SOEs such as Ereğli Iron-Steel Plant and PETKİM, and many private manufacturing industries such as textile, food products, and durable goods such as automotive, washing machine, fridge etc. have started to produce them and technology has diffused more than ever after technological developments, infrastructure investments, and increase in purchasing power (Pamuk, 2016).

There are some critiques for previous periods in the fourth 5YDP such as: in 1977, higher share of R&D expenditure budget was devoted for public sector except

⁴³ For instance, Devrim automobile was produced and was approximately ten times expensive than an imported automobile and could not be driven even a few kilometers (Kepenek, 2020).

universities; the insufficiency of R&D expenditure and its share in GDP and uncertainty of national S&T policy for domestic technology were significant problems for R&D; the network between R&D and industry could not be created; and manufacturing firms generally import technology from other countries because of the less cost in the short run for firm but its alternative costs are higher in the long run at the macro level (SPO, 1979). Ayhan (2002) emphasized many absences and events of the third 5YDP such as: there were not essential organizational structure and infrastructure that provide flow of information for technology transfer; there was not an adaptation between transferred advanced technology and country; research opportunities were limited; the ability of academicians was not enough to improve the level of technology; and researchers who studied abroad could not be beneficial for economic development.

- IV. 5YDP: The fourth 5YDP comprises the period between 1979 and 1983. In this plan, there are some aims and developments in terms of education, S&T, and R&D (SPO, 1979) such as: creating training programs for iron steel industry, and promoting scientific research in this sector; developing technological R&D departments that supports industry in terms of production and improvement of its own technology; devoting more resources to R&D; creating research departments in many sectors such as ceramic, chemical, and paper.

Ayhan (2002) pointed out that R&D was not compulsory requirement for foreign direct investors since 1970s because there was not a comprehensive national S&T policy. According to Türkcan (2009), the fourth plan was the last of classic plans that used technology policy term instead of science policy, and it was abolished after two years.

- V. 5YDP: The fifth 5YDP comprises the period between 1985 and 1989. In this plan, there are some aims and developments in terms of education, S&T, and R&D (SPO, 1985) such as: determining target sectors; increasing studies on selecting technology and on adaptation of it for optimal technology transfer; promoting specialization of universities and

cooperation between university and industry; preparing long term S&T main plan based on the study of Turkish Science Policy 1983-2003 that published in 1983 ; improving foreign language level of academicians and promoting teaching in English in some fields.

The fifth plan was prepared with 1 year delay. It gave place to S&T and research in only one page, and repeated previous sentences by referencing Turkish Science Policy 1983-2000 document. According to Türkcan (2009), it is seen that there is a tendency to prepare science policy separately, in other words, determination of long-term strategic S&T policies came to the fore instead of 5YDPs.

- VI. 5YDP: The sixth 5YDP comprises the period between 1990 and 1994. In this plan, there are some aims and developments in terms of education, S&T, and R&D (SPO, 1994) such as: providing supports for scientific research activities in medical and for monitoring new fields in medical and modern medical technology; taking steps for increasing the number of academician and teachers such as leading young and hardworking students to be academician; doubling the number of research personnel; increasing the share of R&D expenditure in GDP over 1%; providing advanced technology through technology transfer; supporting R&D activities in many fields with advanced technologies such as biotechnology, information technology, microelectronic, telecommunication, satellite technology, nuclear technology, and new materials; closing the information gap between Türkiye and developed countries by generating software industry and increasing labor supply in information technology sector; increasing supports to universities for applied and basic researches; spreading techno parks that support cooperation between university and industry; establishing knowledge bank and semi-independent patent office; creating R&D Fund to lead R&D researches to critical fields and to commercialize new ideas in S&T for economy.

According to Ayhan (2002), first targets for S&T were in the sixth plan, such as ‘doubling the number of research personnel’ and ‘increasing the share of R&D

expenditure in GDP over 1%'. As a result of continued R&D investments and increase in the research capacity in universities during the period of the sixth plan, there were some developments in S&T such as increase in the number of publications annually (from 520 to 1789) and rise of its international rank (from 44 to 34) in the period between 1986 and 1994, respectively, and establishing five techno parks and two high technology institutions (SPO, 1996). According to Türkcan (2009), it can be said that Turkish S&T system in maturity stage after Technology Development Foundation of Türkiye and Turkish Academy of Sciences were founded. Moreover, in this plan, many issues such as information society, information technology, and software industry were emphasized.

There are some critiques for the period so far in the seventh 5YDP such as: targets that determined in the previous plan could not be achieved⁴⁴; integration of scientific developments, increasing technology ability, and education system could not be provided because of S&T policies and sectoral policies were not compatible with each other; strategic priorities of industries by products could not be determined because of the lack of technology inventory; R&D activities could not be institutionalized in public and private institutions; technology infrastructure could not be developed to benefit for economy and within the framework of general policy; technological investments based on production economics could not be done; organizational structures that support R&D could not be developed such as financial and administrative institutions, techno parks, and venture capital institutions; there was not activities that unify economic needs and generic technologies; Türkiye could not reached desired level to produce its own technology; there was not sufficient and continuous financial resources; international competitiveness of Türkiye could not be increased because of the lack of development of innovative technologies based on organizational and coordination deficiencies; the diffusion of international internet networks and services in telematics could not be provided efficiently; there was a lack of experience in R&D sector for studying on a big project together with many

⁴⁴ The share of R&D expenditure in GDP was 0.5% (target was 1%) (2% in EU countries, 2.8% in USA, 3% in Japan) and the number of researchers per ten thousand employments (FTE) were 7.5 (target was 15) in Türkiye (40 in EU countries, 80 in USA, and 90 in Japan) (SPO, 1996).

researchers; subsidy policies were insufficient to meet technological needs; and Türkiye has spent its limited currency sources to transfer technology (SPO, 1996).

- VII. 5YDP: The seventh 5YDP comprises the period between 1996 and 2000. In this plan, there are some aims and developments in terms of education, S&T, and R&D such as: generating sturdy basis for by developing education system, R&D institutions, universities, and manufacturers; providing connection between the policies of science-technology-industry and the policies of education-R&D; revising employee personal rights of research personnel; coordination between private and public sector has been started; spreading advanced technologies; increasing the share of R&D expenditure in GDP as 1.5% in the early 2000s and the number of researchers per ten thousand employment (FTE) as 15; supporting to increase in the share of private sector in R&D expenditure; S&T, education and R&D became primary fields to invest; developing education system to support R&D; generating National R&D Network that includes R&D institutions of private and public sectors and universities; developing cooperation of international S&T with countries such EU, Japan, and USA; allocating sources for defense industry; techno park activities have continued to develop cooperation between university and industry; regulating rules to support R&D; spreading researches by focusing on advanced technology, design, product development, ICT, nuclear, new materials, techno parks, space and military technologies, medical, environment, robotics, biotechnology, marine sciences and technologies etc.; increasing competitiveness in terms of information technology and software by generating programs to educate people and supporting software industry; and generating intellectual and industrial property rights system SPO (1996).

There are some critiques for the period so far (1960-2000) in the Long-Term Strategy and VIII. 5YDP such as: sufficient source for R&D could not be devoted although it was target in the seventh plan; supporting people to study abroad for master

and doctoral research; universities could not be rescued from centralistic and bureaucratic structure; competitive environment among universities could not be generated; academicians' authority could not be increased; and participation of academicians in the administrative process, scientific autonomy, and cooperation between university and industry could not be provided; R&D expenditure and the number of researchers could not be increased sufficiently⁴⁵ especially during the period of seventh plan; physical infrastructure for researchers and their employment and work conditions could not be enhanced (SPO, 2001). In the seventh plan, infrastructure, subsidy, and investment policies that support industrial production were so weak (Ayhan, 2002; Türkcan, 2009).

- Long Term Strategy and VIII. 5YDP: The long-term strategy and VII. 5YDP comprises the period between 2001 and 2005. In this plan, there are some aims and developments in terms of education, S&T, and R&D such as: activating a control mechanism for public financial supports; generating data about sector and products by doing their market research activities; increasing R&D expenditure of universities to support increase in total factor productivity; supporting research activities about monitoring population structure; strengthening medical faculties in terms of education, research, labor force, and infrastructure instead of opening new ones; supporting R&D activities of unions; developing physical, human and legal infrastructure to support R&D; supporting scientific R&D activities; increasing public investments in by focusing fields such as education, health, and technological research (SPO, 2001).

There are some critiques for the period so far in the IX. Development Plan such as: research activities generally were not compatible with the demand and needs of industry because of the lack of strong network among institutions; the share of R&D

⁴⁵ 2006 researchers were supported to study abroad during the period of the sixth plan, and 416 during the period of the seventh plan, and the share of R&D expenditure in GDP was 0.49% and the number of researchers per ten thousand employment (FTE) was 8.2 in 1997 and the aims in the eighth plan were 1.5% and 20 until 2005, respectively (SPO, 2001).

expenditure in GDP was low⁴⁶; there were not a well connection with EU research network because of the lack of R&D infrastructure and researchers; the number of researchers per ten thousand employment (FTE)⁴⁷ and the percentage of researchers who employed in private sector were could not be increased⁴⁸ (SPO, 2007).

- IX. Development Plan: The ninth development plan comprises the period between 2007 and 2013. In this plan, there are some aims and developments in terms of education, S&T, and R&D such as: implementing R&D policies to increase R&D expenditure, the number of researchers; implementing policies to direct researchers to private sector; training researchers and promoting them to work in private sector; implementing policies for remigration of Turkish researchers who live in abroad to employ; developing training programs to increase the labor productivity; spreading venture capital and other tools to support entrepreneurship for technological progress; supporting private sector to establish research institutes/centers in determined fields; establishing a center to research satellite technologies; developing subsectors of electronic components by promoting R&D and by enhancing the capacity of laboratory and research infrastructure; spreading the education programs in the country that aim to promote students to be more innovativeness and research-oriented; establishing technology transfer centers; (SPO, 2007).

Together with this plan, sources devoted to R&D and the number of researchers, and R&D activities, expenditures, and employment of researchers in private sector were increased, and R&D infrastructure were enhanced even though some targets could not be met⁴⁹ (The Ministry of Development, 2014).

⁴⁶ The share of R&D expenditure in GDP was still less than 1% during the period of the ninth plan (0.67% in 2002) (SPO, 2007).

⁴⁷ It was 13.6% in 2002 (66.6% for OECD, on average,) (SPO, 2007).

⁴⁸ Approximately 73% of researchers were employed in higher education sector in Türkiye (but private sector in advanced countries) (SPO, 2007).

⁴⁹ The share of R&D expenditure in GDP was still less than 1% (0.6% in 2006, 0.86% in 2011, target: 2%, EU-average: 1.9%). Moreover, the number of researchers per ten thousand employment (FTE) was 30 in 2011 (Eu-average in 2010: 70.3) (The Ministry of Development, 2014).

- X. Development Plan: The X. Development Plan comprises the period between 2014 and 2018. In this plan, there are some aims and developments in terms of education, S&T, and R&D such as: continuing to increase the number of researchers and their skill more and to promote the employment of researcher in private sector; developing regional and global cooperation in R&D; easing critical technology transfer, and endogenizing and developing it competitively; transforming research centers in universities and public institutions; providing working environment among research centers, incubators, technology transfer and innovation centers, and TDZ that focus on determined fields and supporting their clustering activities; developing relationships among organized industrial zones, TDZ, and research centers; supporting cooperation of SMEs with other institutions and their clustering activities; prioritizing research on nanotechnology and biotechnology; continuing national research ship building; providing supports for rock gas research activities to decrease energy dependence; implementing detailed commercializing program (The Ministry of Development, 2014).

There are some critiques for the X. Development Plan in the XI. Development Plan such as: there is need for knowledge and technology transfer that leads to transform R&D results into economic and social utility; there is also need for development of entrepreneurship and commercialization activities; the need for decrease in the dropout rate of secondary school; determination of higher education quota by considering supply-demand equilibrium and connection between education and employment (The Presidency of Strategy and Budget, 2019).

- XI. Development Plan: The XI. Development Plan comprises the period between 2019 and 2023. In this plan, there are some aims and developments in terms of education, S&T, and R&D such as: transforming manufacturing industry to increase the capacity of innovation; increasing the number of researcher and their qualification in private sector; transforming R&D and innovation support system; implemented many policies about researchers

who have a doctoral degree; matching research universities and prioritized sectors to provide cooperation between them; conducting R&D projects in cooperation between research centers in TÜBİTAK and firms in prioritized sectors; supporting projects that high commercial potential; implementing innovation support coupon program for SMEs that use R&D and innovation project services from R&D infrastructure; generating R&D platforms to promote cooperation among prioritized sectors and industries at national and regional level; providing pioneer research in country to have higher value-added in global value chain; promoting foreign academicians and researchers to employ in universities that specialized in critical technology fields; strengthening research infrastructure in critical technologies; informing researchers in terms of incentive and intellectual property rights to accelerate the process of commercialization; providing country to be a regional leader in terms of clinical research; establishing pre-clinic research centers; completing establishment of National Rail Systems Test and Research Center together with its R&D infrastructure; implementing support programs to research on sectoral market research and topics such as their technology progress, demand for labor force, marketing, and branding; strengthening the relationship between R&D and publication; strengthening R&D infrastructure in universities; developing scientific research projects in terms of quality and quantity; strengthening Research University program by increasing capacity with special supports; increasing the number of postdoc researcher on contract in research universities; supporting researchers who conduct high level scientific and technologic projects, to return to the country and to educate new researchers under the International Leader Researchers Program; generating a mechanism that provide a fund and R&D infrastructure to support pioneer Turkish researchers abroad who conduct part-time education and research activities; increasing the number of R&D personnel and easing requirements for foreign personnel in research infrastructures; increasing the number of qualified labor force who have research

experience by supporting students with scholarship; harmonizing National R&D and Innovation Programs with EU Framework Program for Research and Innovation; strengthening position of the country in terms of Pole researches; completing works on setting up a base in Antarctic and developing organizational capacity for pole research; generating database about patent information related to digital transformation to share with researchers; increasing the capacity and efficiency of TÜRKPATENT; actualizing Digital Transformation Research Program; providing opportunities for secondary education students to attend scientific activities in university and to benefit from laboratories in universities; increasing the number of research assistants in foundation universities; supporting research on preventing brain drain and increasing return to the country; supporting studies on immigration to develop efficient policies based on evidences; supporting studies on civil society activities; establishing research centers focused on Islamic World in universities; and advertising the country internationally with researches and projects (The Presidency of Strategy and Budget, 2019).

In this XI. Development Plan, policies on science, technology, and innovation are explained under the sectoral policies part. Improving research and innovation ecosystem and increasing R&D and innovation activities are emphasized as a main object. In addition, the importance of qualified, strong, and happy people and society are emphasized in terms of sustainable development and economic growth. In terms of education, characteristics of people in society are explained lengthily such as happy, productive, entrepreneurial and innovative peculiarities, and so on. Education policies are based on these characteristics.

In this last plan, priority sectors were determined under the industrial policies such as Chemical Industry, Pharmaceuticals and Medical Devices, Electronics, Machinery and Electrical Equipment, Automotive, and Rail System Vehicles. Moreover, other manufacturing industries were explained as textile-clothing-leather industry, non-metallic mineral products industry, basic metal industry, ship-building

industry, and furniture industry. Priority development areas were determined as Agriculture, Defense Industry, and Tourism.

Development plans since the 1960s were explained by focusing on R&D, S&T, innovation, and education here. This part supports the process of understanding the changes in the policies. In the next part, R&D statistics in Türkiye is visualized by using TURKSTAT's public data on its website. In addition, real growth rates of some statistics such as R&D statistics are calculated and visualized.

2.2. R&D Statistics of Türkiye

R&D activities are essential and indispensable factors for technological progress, and for economic growth and development. R&D indicators and statistics must be viewed to understand the capability of a country and its R&D level in terms of R&D activities.

In recent decades, Türkiye endeavored a lot even though there were some absences such as political, economic, social, and organizational concerns that mentioned before. The last decades of Türkiye in terms of R&D activities are reviewed here with available R&D statistics.

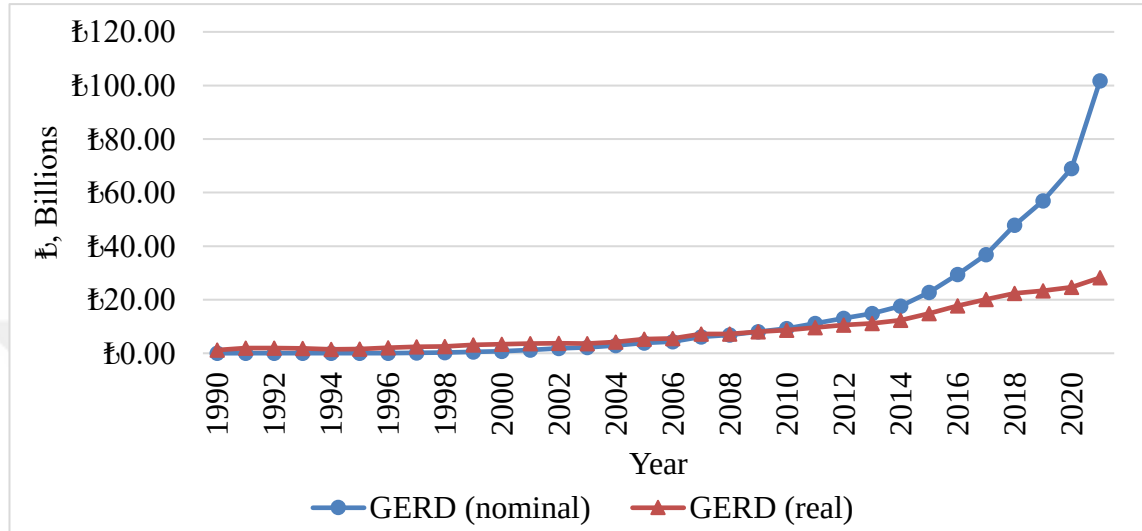
2.2.1. The Gross Domestic Expenditure on R&D (GERD) in General

GERD⁵⁰, one of the well-known and well discussed R&D indicators in literature. GERD has increased nominally in recent decades in Türkiye, which is shown in Figure 1. However, it has not increased in real terms as much as nominal one because of deflator effect. Moreover, it may be said that there is a slowdown of increase in real GERD.

The slowdown in real GERD can be seen clearly by its growth rate over time, which is shown in Figure 2. The growth rate fluctuated a lot during the 1990s, but the fluctuations decreased in the next years, especially during the 2010s. In the long run, there is a light downward trend in the rate. A few years before the 1994 Economic Crisis, it is seen that GERD shrank between 1992 and 1994, for instance approximately

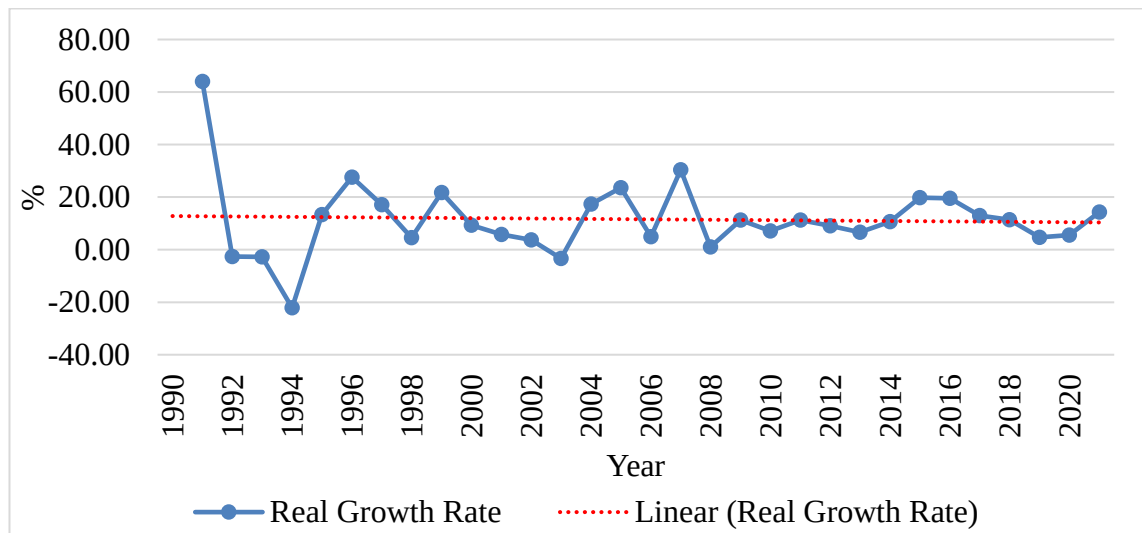
⁵⁰ It is explained as "... total intramural expenditure on R&D performed in national territory in a given period" (TURKSTAT, 2023).

22% (the deepest one) in 1994. The second deepest one was approximately 3.3% in 2003 and the growth rate started to decrease especially after 1999 because of the 1999 Earthquake in Türkiye and the 2001 Turkish Economic Crisis.



Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100. The private non-profit sector has been included in labor costs since 2016.

Figure 1: Gross Domestic Expenditure on R&D (GERD) in Türkiye (1990-2021)

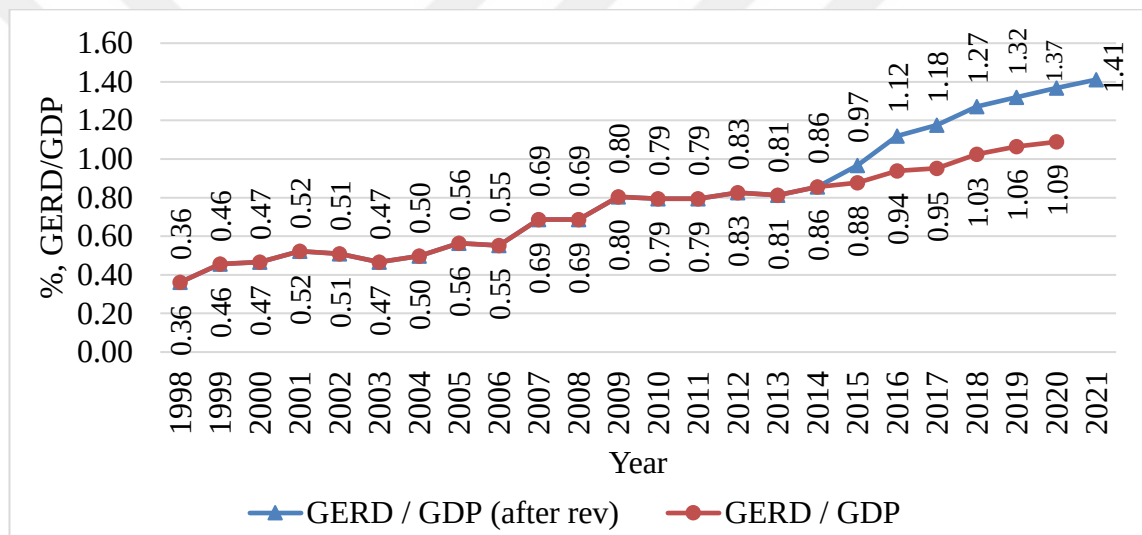


Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100. The private non-profit sector has been included in labor costs since 2016.

Figure 2: Real Growth Rate of GERD in Türkiye

In the shadow of this light downward trend of real growth rate of GERD, the ratio of GERD to GDP could not be increased efficiently and at the desired level in

recent decades, which is shown in Figure 3. The increase in the ratio slowed down in 2000 because of the 1999 Earthquake, and the ratio decreased slightly especially during the early 2000s because of the 2001 Turkish Economic Crisis, and it decreased barely after 2009 because of the 2008 Global Crisis. Because labor costs of the private non-profit sector were added, the ratio increased in the second half of the 2010s. Before this revision, the ratio reached 1% in 2018 eventually, but it passed 1% in 2016 after the revision. In both situations, Türkiye could not meet its targets (such as 2% until 1990 and 1% until 2003) until the second half of the 2010s even though it decreased the target from 2% to 1%.



Source: Derived from TURKSTAT, Research and Development Activities Survey, and Quarterly Gross Domestic Product. The private non-profit sector has been included in labor costs since 2016.

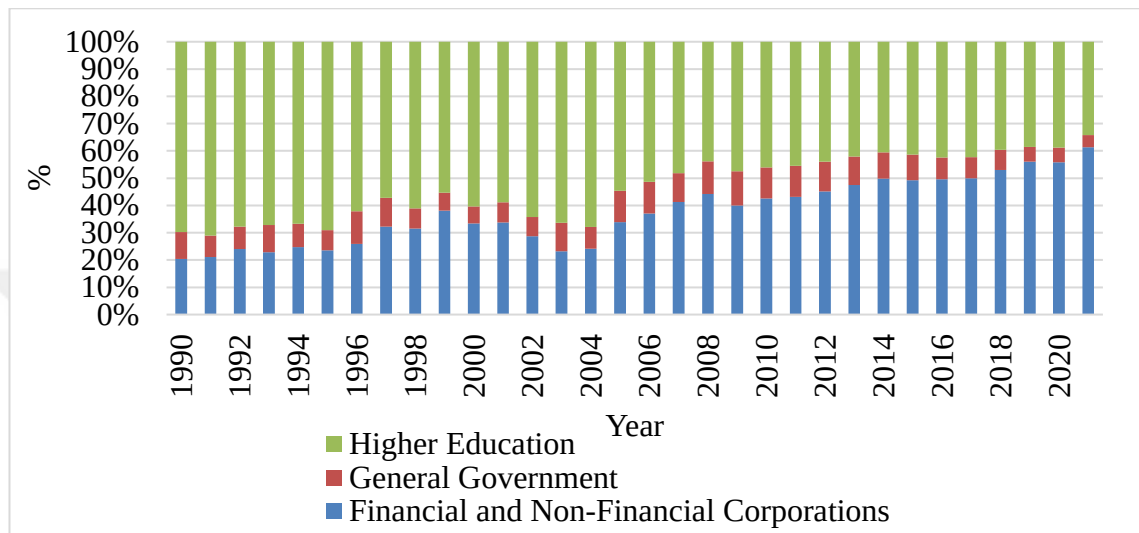
Figure 3: The Ratio of GERD to GDP in Türkiye (1998-2020)

2.2.2. GERD by R&D Sector in General

GERD is reviewed by separating sectors into three groups such as higher education (HE) sector, general government⁵¹ (GG), and financial and non-financial

⁵¹ It is explained as “Government units are unique kinds of legal entities established by political processes that have legislative, judicial or executive authority over other institutional units within a given area. Viewed as institutional units, the principal functions of government are to assume responsibility for the provision of goods and services to the community or to individual households and to finance their provision out of taxation or other incomes, to redistribute income and wealth by means of transfers, and to engage in non-market production. Before 2016 survey, this category was being evaluated in the government enterprise sector” (TURKSTAT, 2023).

corporations⁵² (FNFC), which are shown in Figure 4. Last two decades (except the 2001 Turkish Economic Crisis, and the 2008 Global Crisis), the share of R&D expenditure of HE sector has decreased while the share of R&D expenditure of FNFC sector has increased.



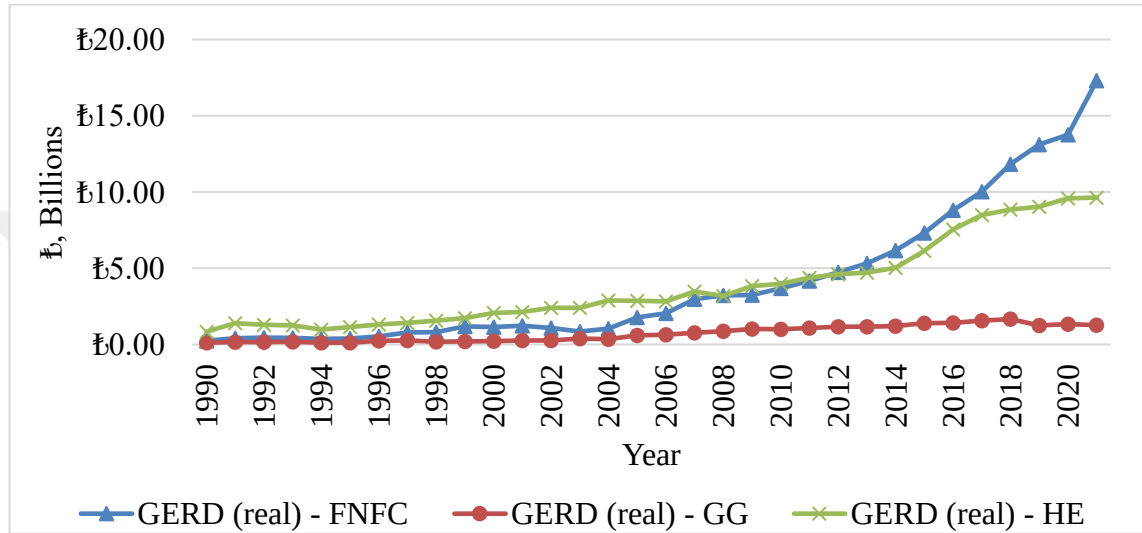
Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100. The private non-profit sector has been included in labor costs since 2016.

Figure 4: Distribution of GERD by Sectors

It is seen in Figure 4 that the share of R&D expenditure of HE sector was substituted for the R&D expenditure of FNFC sector to mitigate the impacts of the crises on the R&D expenditure. It is clearly seen in the Figure 5, FNFC sector increased its R&D expenditure dramatically in the 2000s and real R&D expenditure of FNFC sector passed the real R&D expenditure of HE sector in 2012 because of The Law on Technology Development Zones No.4691 in 2001, Law on Supporting R&D and Design Activities No.5746 in 2008, and many subsidies such as Cabinet Decree No.2012/3305 on R&D subsidies in 2012. Until 2012, 44 TDZ (or techno parks) were established (82 in 2018, and 15 in infrastructure development phase in 2023) (The Ministry of Industry and Technology, 2023). The share of R&D expenditure of GG

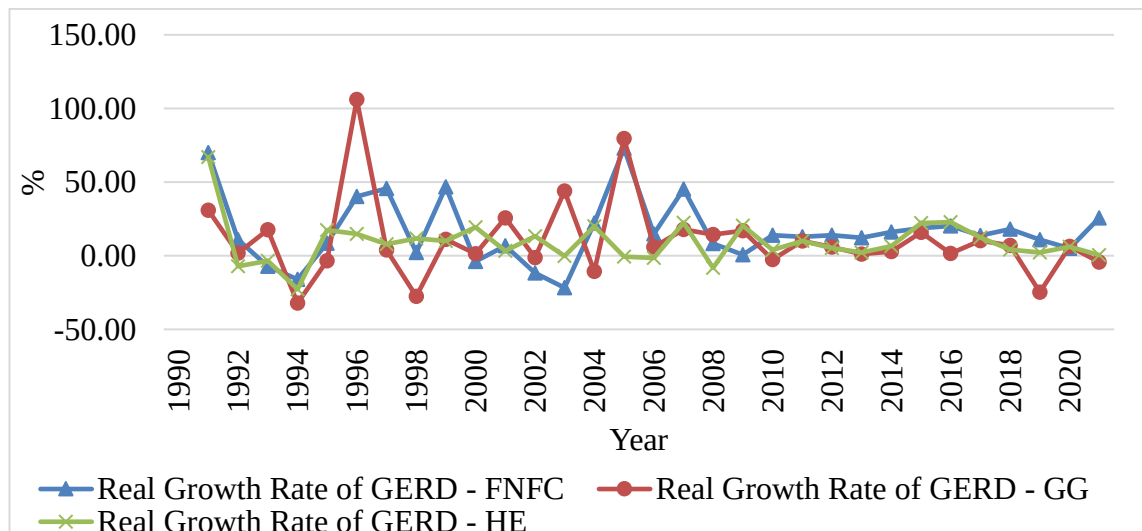
⁵² Financial one is explained as “... all resident corporations that are principally engaged in providing financial services, including insurance and pension funding services, to other institutional units ...”, and non-financial one is explained as “... corporations whose principal activity is the production of market goods or non-financial services ...” (TURKSTAT, 2023).

sector, the least one, was generally between 7% and 13%, like a stabilizer among the others. The real growth rate of R&D expenditure of GG sector (approximately 25%) was more than the rate of FNFC sector (approximately 6%) in 2001, and approximately 43% (GG sector) and 22% (FNFC sector) in 2003, approximately 14% and 8% in 2008, 0.6% and 14% in 2009 respectively, which are shown in Figure 6.



Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100. The private non-profit sector has been included in labor costs since 2016.

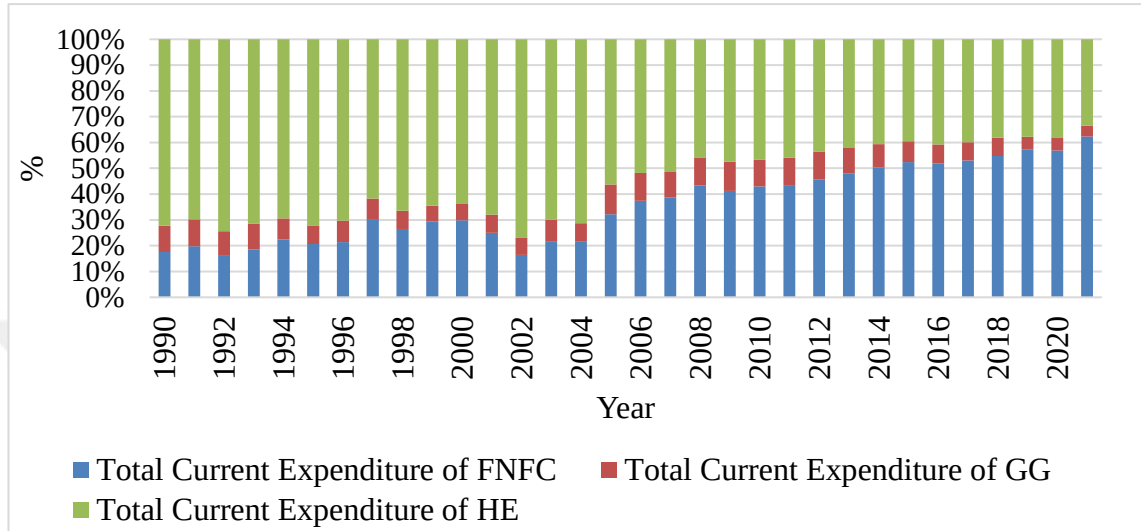
Figure 5: Real GERD by Sectors



Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100. The private non-profit sector has been included in labor costs since 2016.

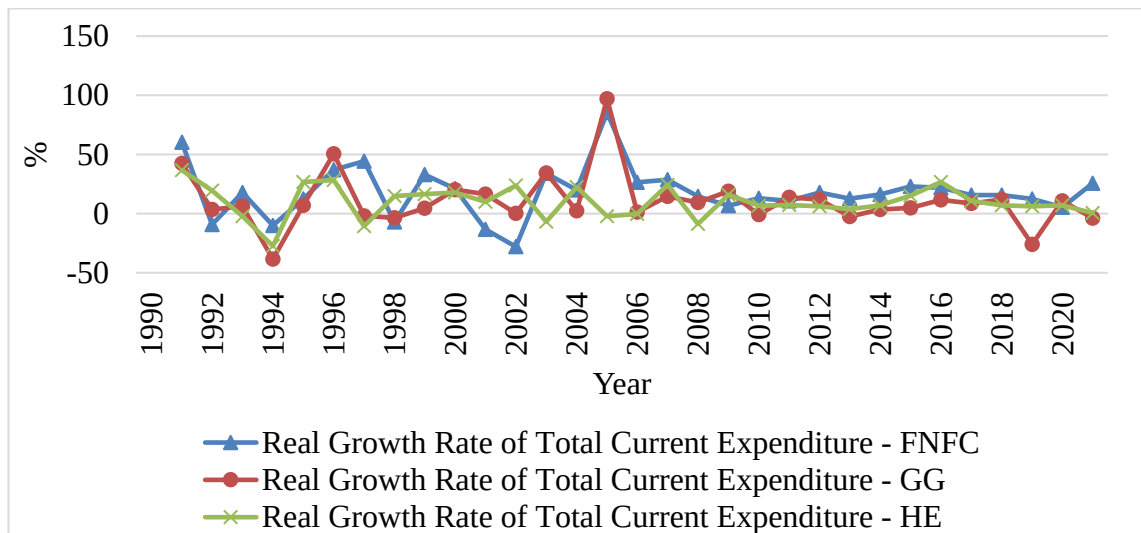
Figure 6: Real Growth Rate of GERD by Sectors

GERD is the sum of current and capital R&D expenditure. It is seen in Figure 7 that the share of total current expenditure of FNFC sector increased generally except for some years around economic crises.



Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100. The private non-profit sector has been included in labor costs since 2016.

Figure 7: Distribution of Total Current Expenditure by Sectors



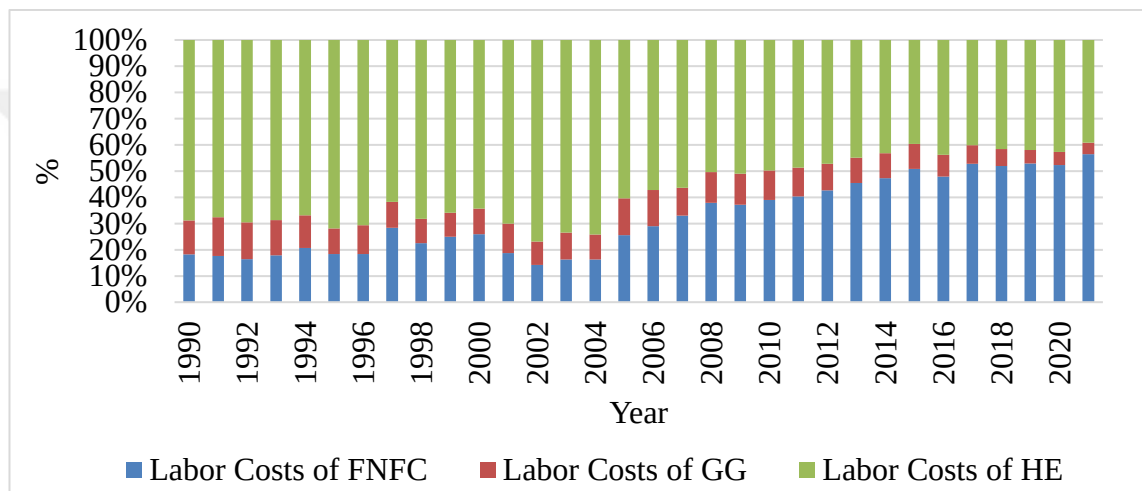
Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100. The private non-profit sector has been included in labor costs since 2016.

Figure 8: Real Growth Rate of Total Current Expenditure by Sectors

The growth rate of total current expenditure in each sector decreased a few years before the 1994 Crisis, the 1997-98 Crisis, and the 2001 Crisis, which are shown

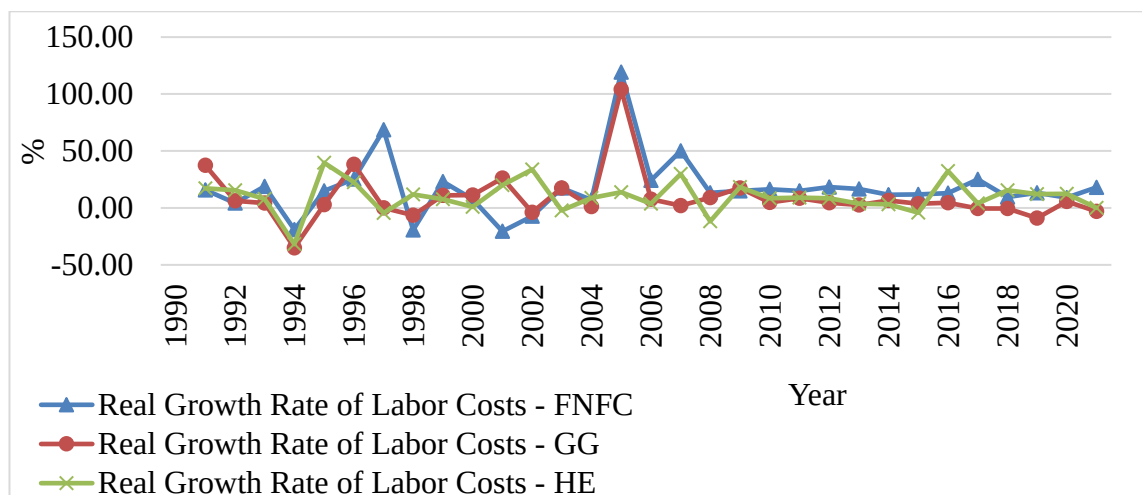
in Figure 8. Total current expenditure of FNFC sector shrank in 1992, 1994, 1998, 2001, and 2002, and of GG sector in 1994, 1997, 1998, 2013, 2019, and 2021, and of HE sector in 1993, 1994, 1997, 2003, 2005, 2006, and 2008.

Total current R&D expenditure is the sum of labor costs and other current costs. The share of labor costs of HE sector is the biggest one until 2013, which is shown in Figure 9. In the last three decades, the share of labor costs of FNFC increased except the years during the crises.



Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100. The private non-profit sector has been included in labor costs since 2016.

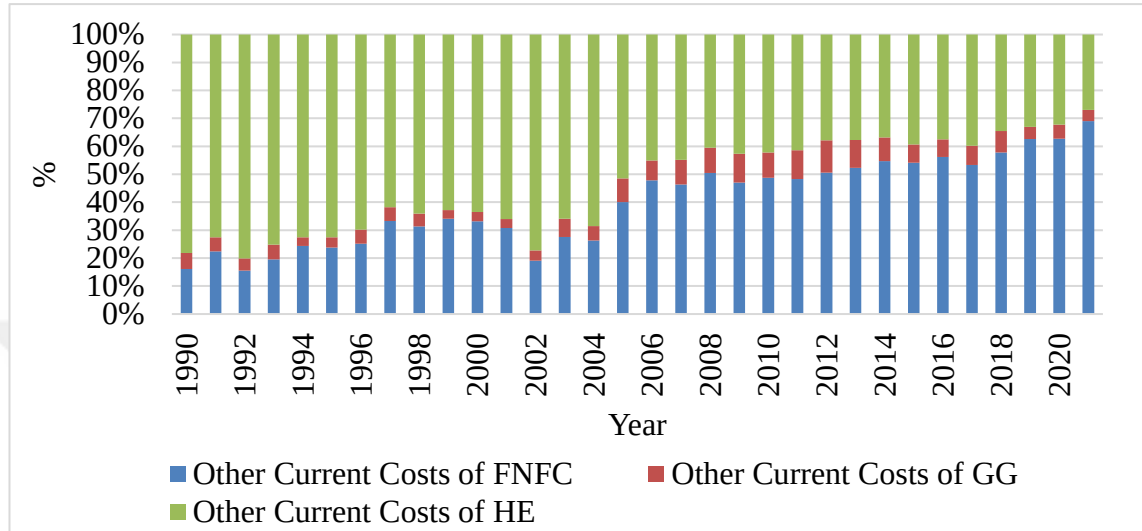
Figure 9: Distribution of Labor Costs in GERD by Sectors



Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100. The private non-profit sector has been included in labor costs since 2016.

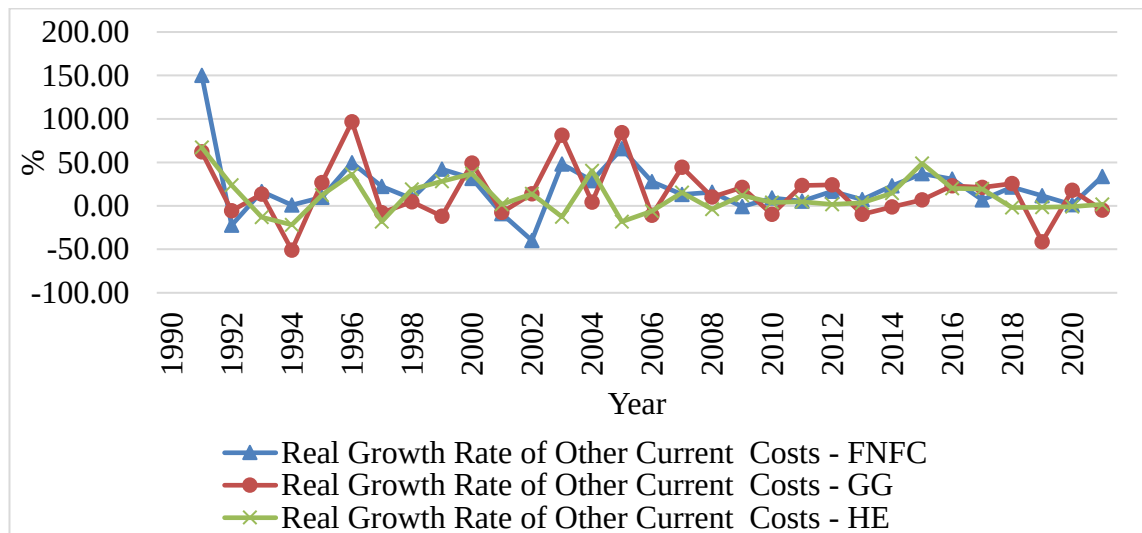
Figure 10: Real Growth Rate of Labor Costs by Sectors

The share of other current costs of HE sector is the biggest one until 2006, which is shown in Figure 11. In the last three decades, the share of labor costs of FNFC increased except the years during the crises.



Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100. The private non-profit sector has been included in labor costs since 2016.

Figure 11: Distribution of Other Current Costs in GERD by Sectors

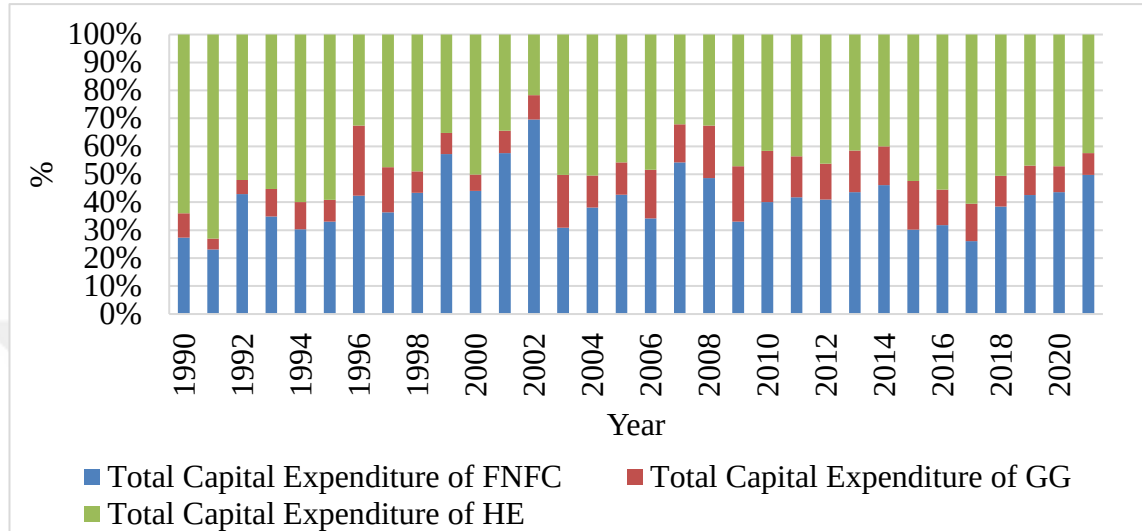


Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100. The private non-profit sector has been included in labor costs since 2016.

Figure 12: Real Growth Rate of Other Current Costs by Sectors

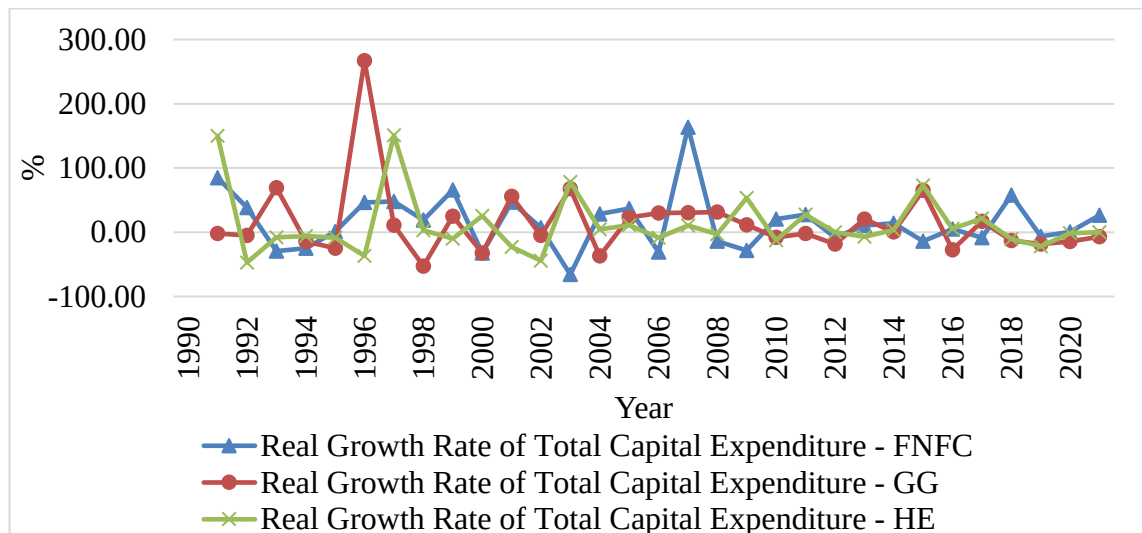
Another part of GERD is the capital R&D expenditure. The share of capital R&D expenditure of HE sector is generally more than the share of FNFC sector except

for some years, which is shown in Figure 13. In the last three decades, the share of capital R&D expenditure by sector changed rapidly year by year and the expenditure shrank generally, , which is shown in Figure 14.



Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100. The private non-profit sector has been included in labor costs since 2016.

Figure 13: Distribution of Total Capital Expenditure by Sectors

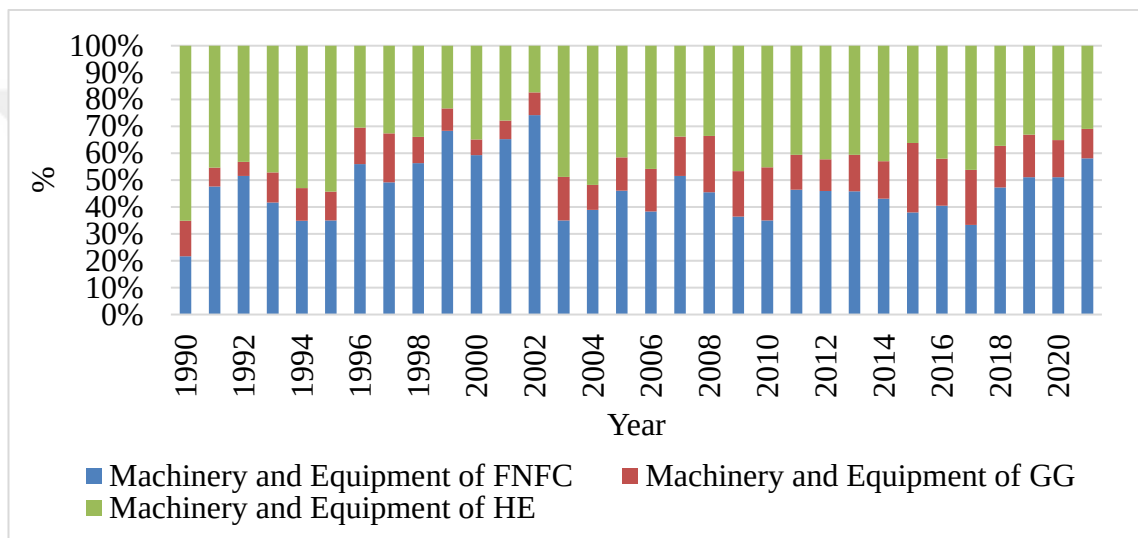


Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100. The private non-profit sector has been included in labor costs since 2016.

Figure 14: Real Growth Rate of Total Capital Expenditure by Sectors

The capital R&D expenditure is the sum of expenditures of machinery and equipment, land and buildings, capitalized computer software, and other intellectual property products.

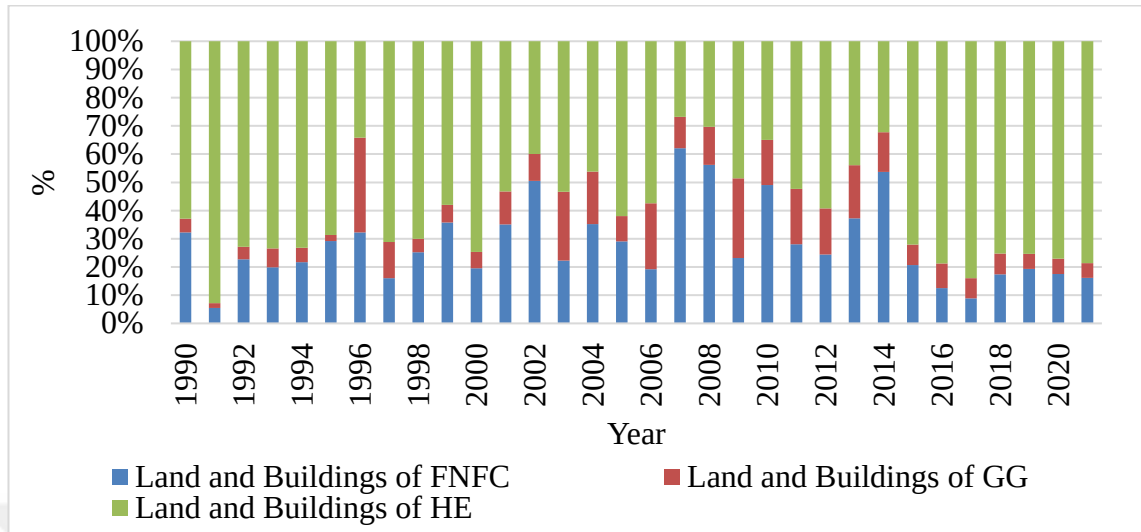
The share of machinery and equipment R&D expenditure of HE sector is generally more than the share of other sectors except for some years, which is shown in Figure 15. In the last three decades, the share of machinery and equipment R&D expenditure of FNFC sector increased before 2002 except during the crises.



Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100. The private non-profit sector has been included in labor costs since 2016.

Figure 15: Distribution of Machinery and Equipment Costs in GERD by Sectors

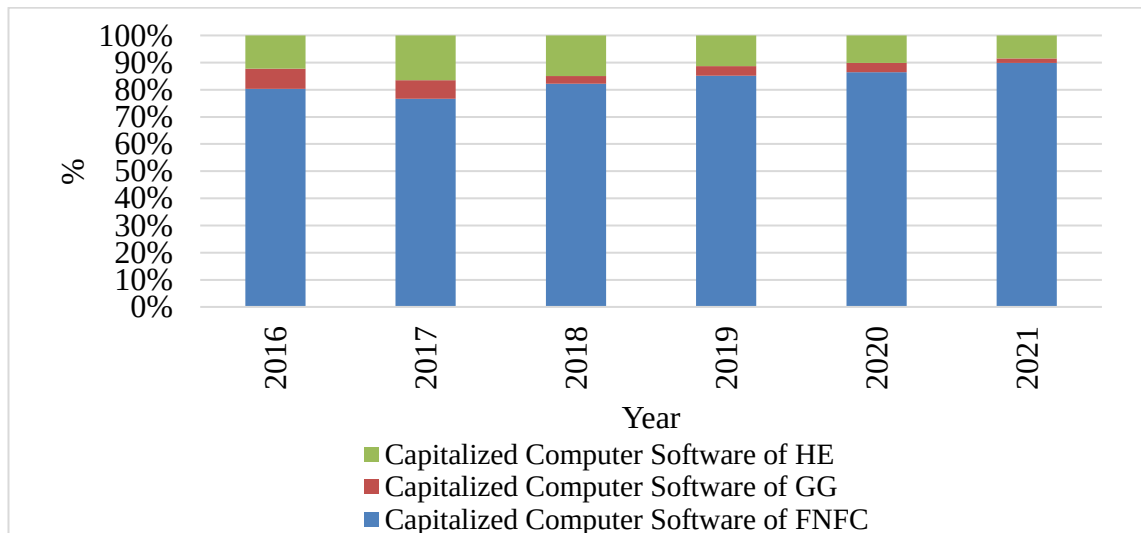
The share of land and buildings R&D expenditure of HE sector is generally more than the share of other sectors except for some years, which is shown in Figure 16. The share of land and buildings R&D expenditure of GG sector is the least and generally increased after economic crises more such as in 1996, 2003, and 2009 while the share of land and buildings R&D expenditure of FNFC sector decreased. In the 21st century, 97 techno parks and more than 130 universities were established in Türkiye and that is why land and buildings R&D expenditure of HE sector is more than the others. The other reason is that investment in land and buildings is so costly for a firm in FNFC sector.



Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100. The private non-profit sector has been included in labor costs since 2016.

Figure 16: Distribution of Land and Buildings Costs in GERD by Sectors

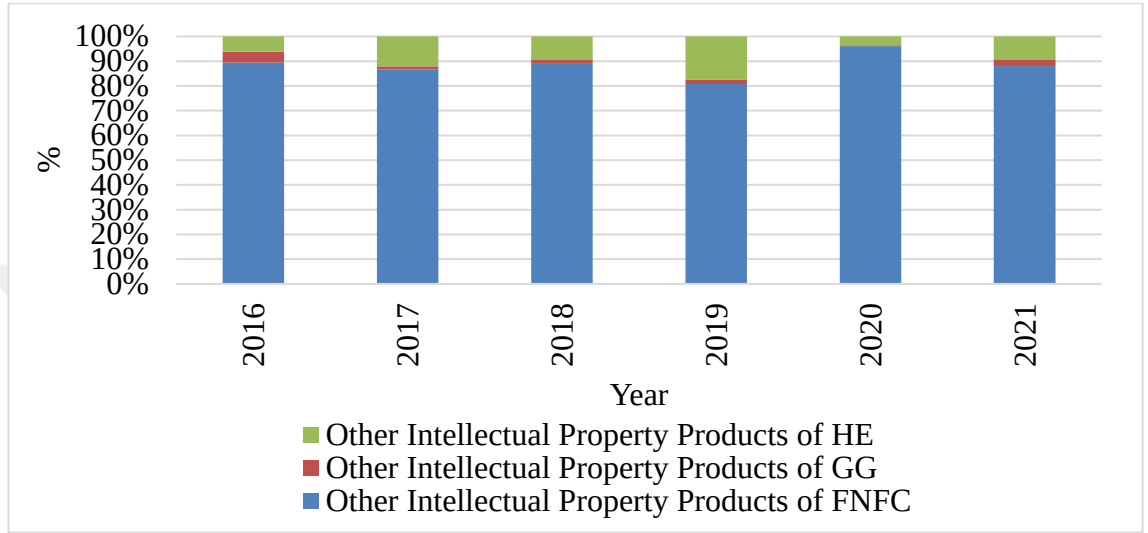
The share of capitalized computer software R&D expenditure of FNFC sector is the highest and approximately %85 on average, and the share of it of HE sector is more than 10% generally, which is shown in Figure 17. Because of lack of data, there is no information about it before 2016.



Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100. The private non-profit sector has been included in labor costs since 2016.

Figure 17: Distribution of Capitalized Computer Software Costs in GERD by Sectors

The share of other intellectual property products R&D expenditure of FNFC sector is the highest and approximately %88 on average, and the share of it of HE sector is the second highest one, approximately 9% on average, which are shown in Figure 18. Because of lack of data, there is no information about it before 2016.



Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100. The private non-profit sector has been included in labor costs since 2016.

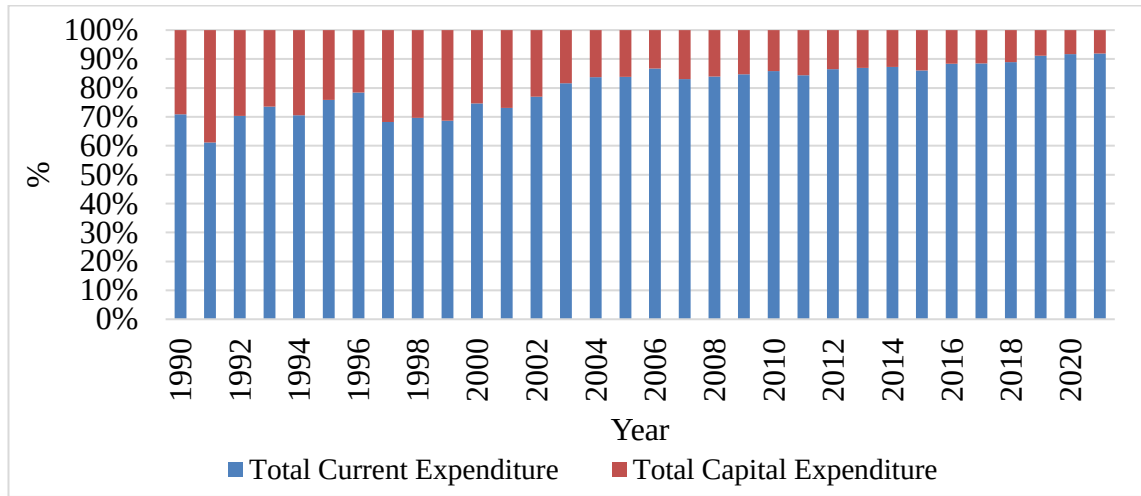
Figure 18: Distribution of Other Intellectual Property Products Costs in GERD by Sectors

2.2.3. GERD by Types of Expenditure in General

GERD is reviewed by separating it into two types of expenditure such as current expenditure⁵³ and capital expenditure⁵⁴, in other words GERD is the sum of both. The share of total capital expenditure in GERD decreased while the share of total current expenditure in GERD increased in recent decades, which is shown in Figure 19. It is seen that the share of total current expenditure in GERD was approximately 70% before 2000 and increased to 90% after 2000, which is shown in Figure 19, because of shrinkage of capital expenditure in most years, which is shown in Figure 20.

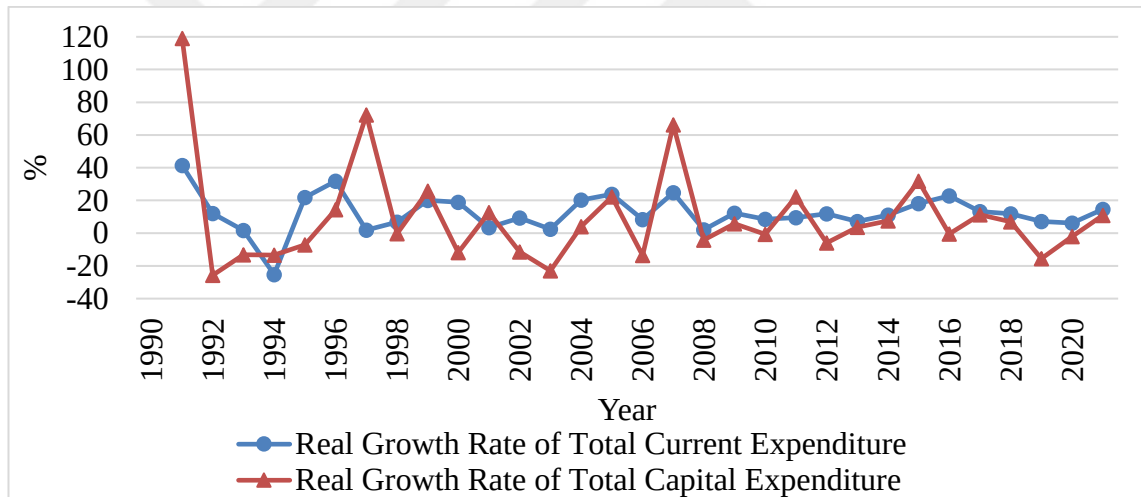
⁵³ Labor costs + other current costs.

⁵⁴ Instruments and equipment + land and buildings + capitalized computer software + other intellectual property products.



Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100. The private non-profit sector has been included in labor costs since 2016.

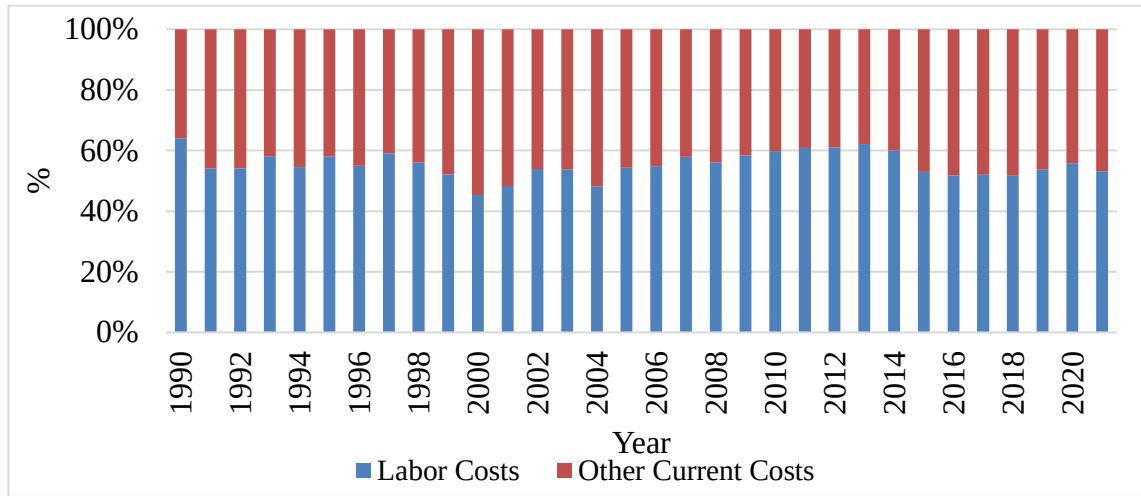
Figure 19: Distribution of GERD by Types of Expenditure



Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100. The private non-profit sector has been included in labor costs since 2016.

Figure 20: Real Growth Rate of GERD by Types of Expenditure

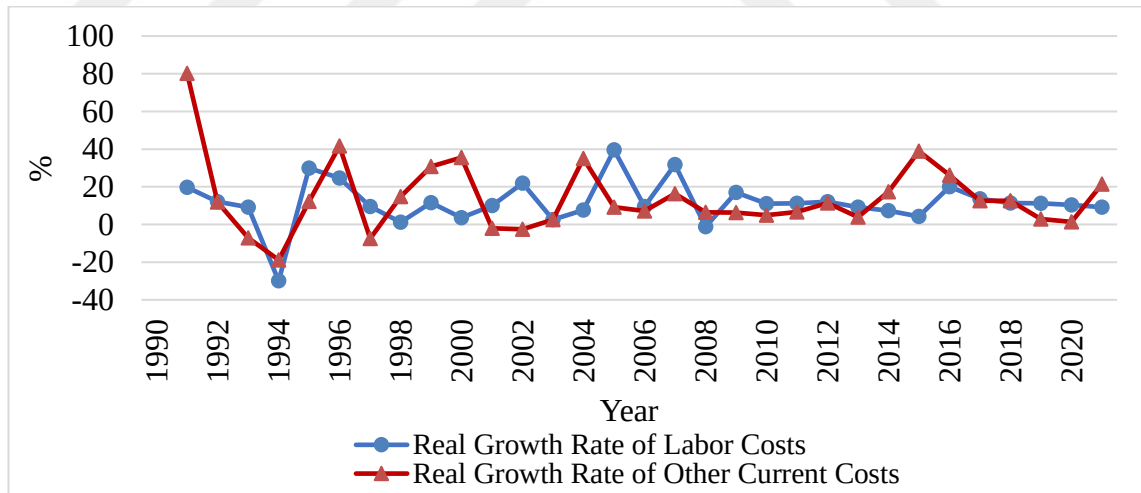
Changes in the distribution of both expenditures can be seen better with the real growth rate of both expenditures that have changed over time, which is shown in Figure 20. It is seen that the real growth rate of total current expenditure was generally positive except 1994 because of the 1994 Economic Crisis in Türkiye. However, the real growth rate of total capital expenditure was negative during the half of the period (not consecutively). It may be because capital R&D investments are costly and there were many economic and political instabilities in Türkiye in the last three decades.



Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100. The private non-profit sector has been included in labor costs since 2016.

Figure 21: Distribution of Total Current Expenditure in GERD by Costs

Total current expenditure, a kind of short-term expenditure, includes labor costs⁵⁵ and other current costs⁵⁶. The share of labor costs in total current expenditure was the highest one except 2000 and 2001, and 2004, which is shown in Figure 21.



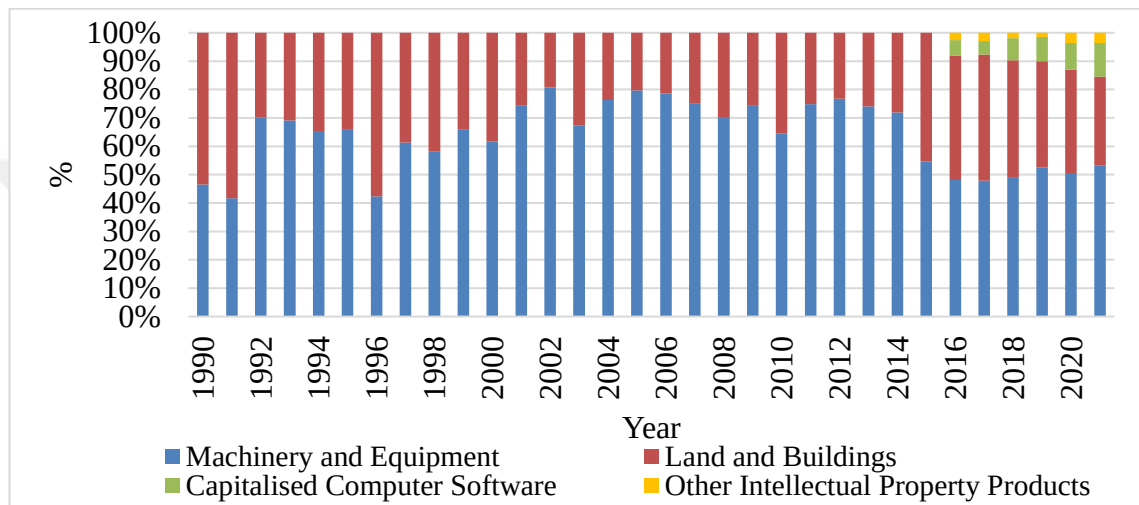
Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100. The private non-profit sector has been included in labor costs since 2016.

Figure 22: Real Growth Rate of Total Current Expenditure in GERD by Costs

⁵⁵ It is explained as “R&D personnel costs include annual wages and salaries and all associated costs or fringe benefits, such as bonus payments, holiday pay, contributions to pension funds and other social security payments, payroll taxes, etc” (TURKSTAT, 2023).

⁵⁶ It is explained as “These other costs include non-capital purchases of materials, supplies and equipment to support R&D performed by the statistical unit in a given year” (TURKSTAT, 2023).

The real growth rates of both labor and other current costs show the slowdown and negative values of the rate over time, which is shown in Figure 22. It is clearly seen that both growth rates were negative in 1994 because of the 1994 Economic Crisis, and only the growth rate of other current costs are also negative in 1993, and negative in 1997 because of the Asian Financial Crisis, and negative in 2001 and 2002 because of the 2001 Turkish Economic Crisis.



Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100.

Figure 23: Distribution of Total Capital Expenditure in GERD by Costs

Total capital expenditure includes machinery and equipment⁵⁷, land and buildings⁵⁸, capitalized computer software⁵⁹, and other intellectual property products⁶⁰. Distribution of total capital expenditure in GERD by costs is important to understand what share of these costs are, which is shown in Figure 23. For example, the share of machinery and equipment in total capital expenditure is the highest one except 1990, 1991, 1996, and between 2016 and 2018. The share of land and buildings

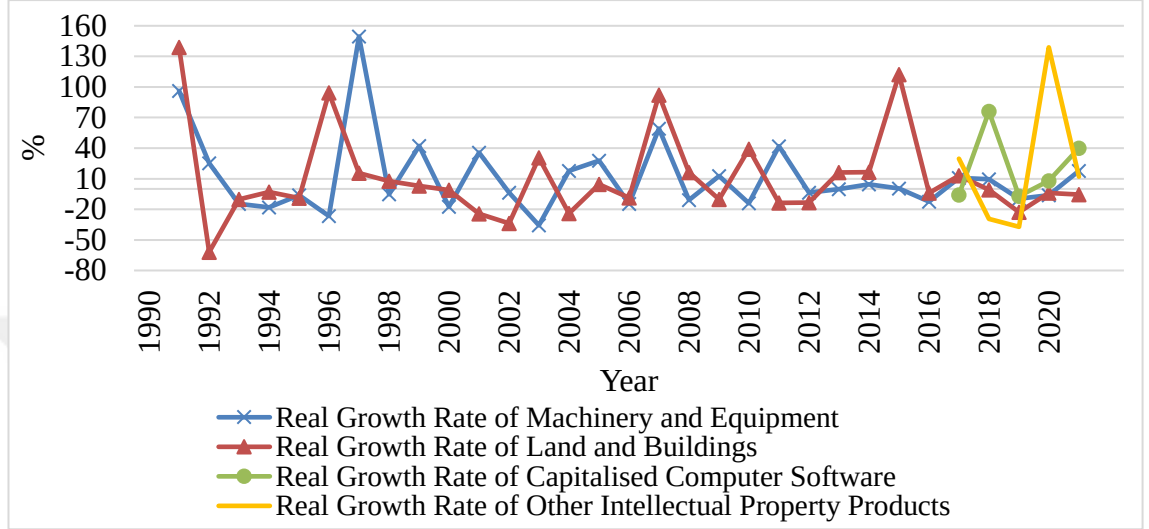
⁵⁷ It is explained as “... acquired for use in the performance of R&D” (TURKSTAT, 2023).

⁵⁸ It is explained as “... land acquired for R&D (e.g., testing grounds, sites for laboratories and pilot plants) and buildings constructed or purchased, including major improvements, modifications and repairs” (TURKSTAT, 2023).

⁵⁹ It is explained as “... consists of computer software that is used in the performance of R&D for more than one year, ... long-term licenses or the acquisition of separately identifiable computer software, including program descriptions and supporting materials for both systems and applications software” (TURKSTAT, 2023).

⁶⁰ It is explained as “patent purchases for longer than one year and used for R & D refer to long term licenses and other intellectual property rights” (TURKSTAT, 2023).

in total capital expenditure is the second highest one. After 2016, expenditures of capitalized computer software and other intellectual property products can be viewed, and their shares increased year by year.



Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100.

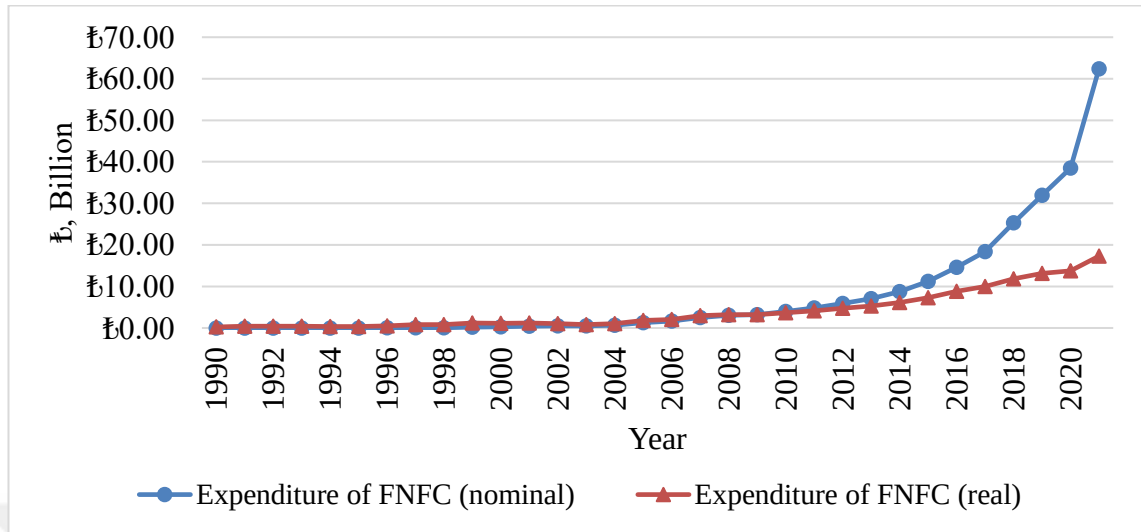
Figure 24: Real Growth Rate of Total Capital Expenditure in GERD by Costs

2.2.4. GERD by R&D Sector in Detail

2.2.4.1. R&D Expenditure in Financial and Non-Financial (FNFC) Sector in Detail

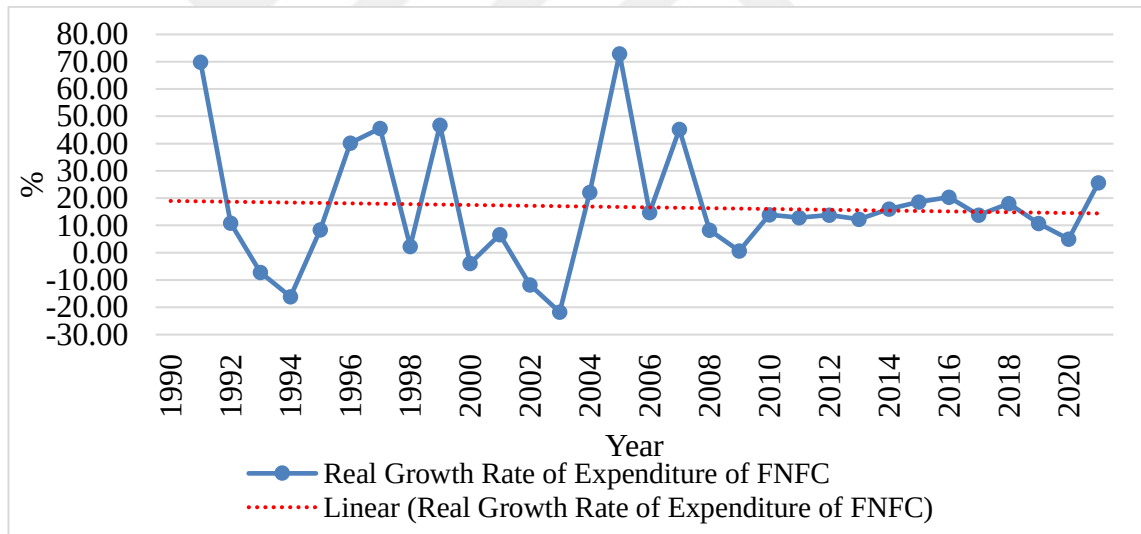
Total R&D expenditure of FNFC sector has increased nominally in recent decades in Türkiye but it has not increased in real terms as much as nominal one because of deflator effect. The real one is not more than ₺10 billion. Moreover, a slowdown of increase in this expenditure as a real term is seen in Figure 25.

The real growth rate of *total R&D expenditure* of FNFC sector showed a downward trend in the last three decades, more changeable before 2000 but stable after the 2008 Crisis, which is shown in Figure 26. During the years around 1994 and 2001, the *total R&D expenditure* of the FNFC sector shrank because of the 1994 Economic Crisis and the 2001 Economic Crisis. The growth rate of this expenditure in 2003 was the deepest, approximately 22%. The rate in 1994 was the second deepest one, approximately 16%.



Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100. The private non-profit sector has been included in labor costs since 2016.

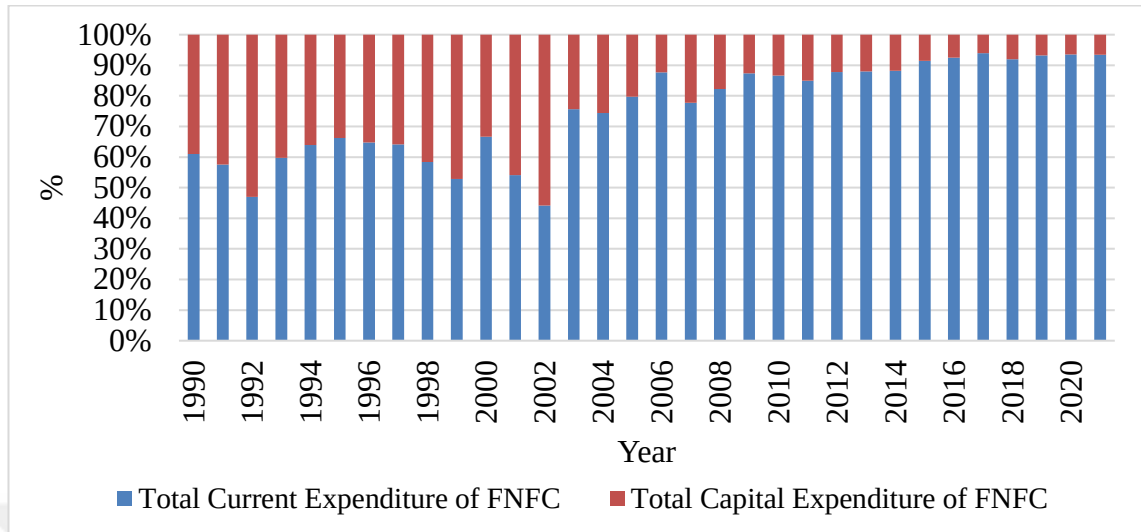
Figure 25: Total R&D Expenditure of FNFC Sector in GERD



Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100. The private non-profit sector has been included in labor costs since 2016.

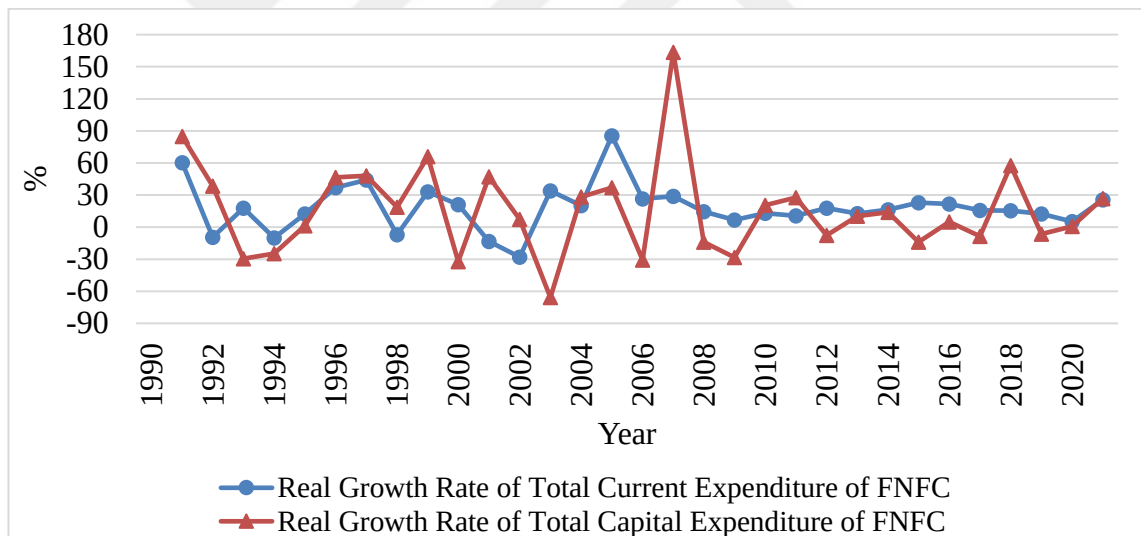
Figure 26: Real Growth Rate of Total R&D Expenditure of FNFC Sector

Distribution of *total R&D expenditure* of FNFC sector by types of expenditure such as total current and total capital expenditures can be seen in Figure 27. The share of total current expenditure increased generally while the share of total capital expenditure decreased.



Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100. The private non-profit sector has been included in labor costs since 2016.

Figure 27: Distribution of Total R&D Expenditure of FNFC Sector by Types

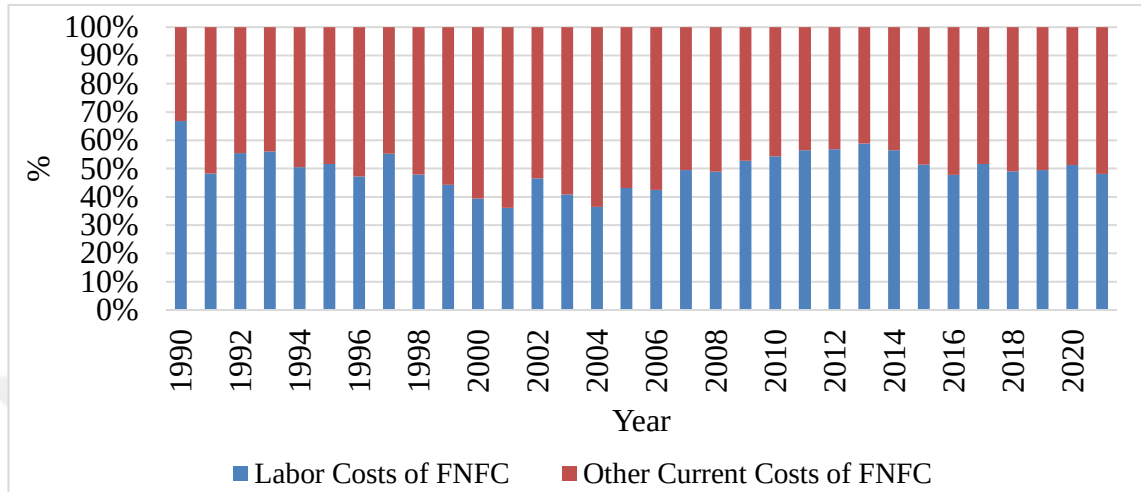


Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100. The private non-profit sector has been included in labor costs since 2016.

Figure 28: Real Growth Rate of Total R&D Expenditure of FNFC Sector by Types

The share of total capital expenditure of FNFC sector shrank in the last three decades generally, which is shown in Figure 27, while the real growth rate of total current expenditure of FNFC sector was positive generally, which is shown in Figure 28, because of costly capital investment and economic and political instabilities in

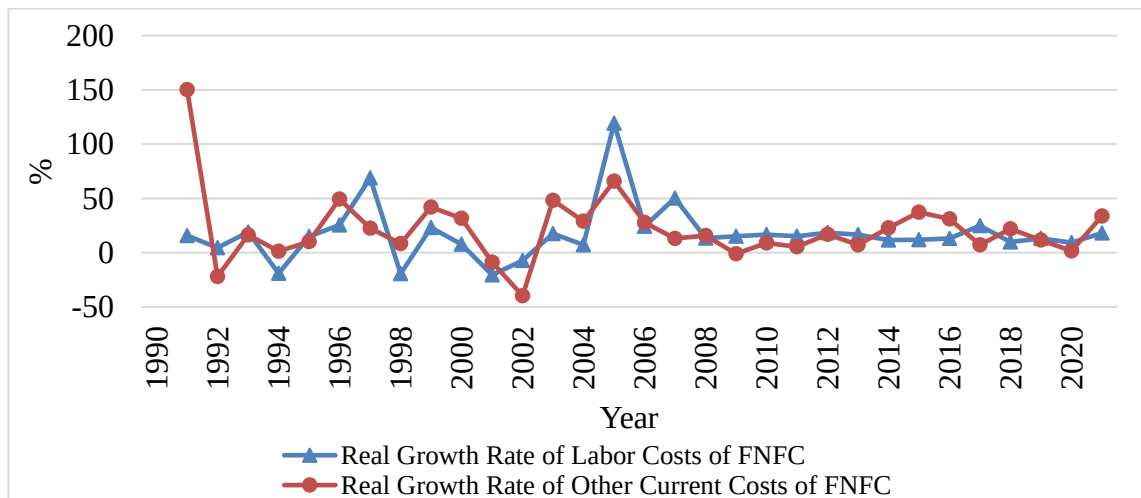
Türkiye. During the years around 1994 and 2001, the real growth rate of total current expenditure was negative because of the economic crises.



Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100. The private non-profit sector has been included in labor costs since 2016.

Figure 29: Distribution of Current Expenditure of FNFC Sector by Costs

Distribution of current R&D expenditure of FNFC sector by costs such as labor and other current costs can be seen in Figure 29, in other words total current expenditure is the sum of them. In the FNFC sector, the shares of both costs were close to each other except for 1990, the early 2000s and the early 2010s, which are shown in Figure 29.

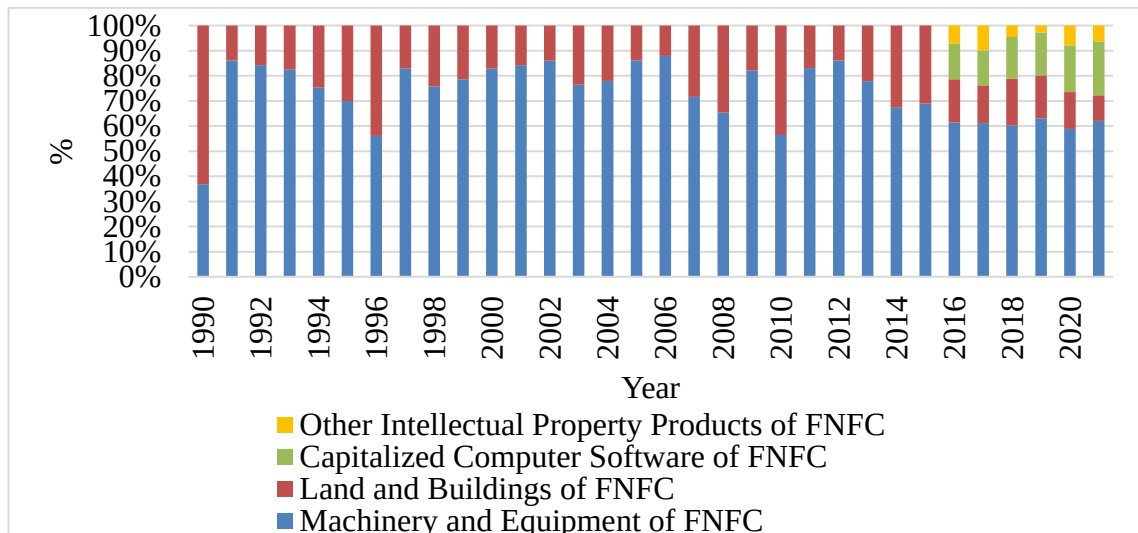


Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100. The private non-profit sector has been included in labor costs since 2016.

Figure 30: Real Growth Rate of Current Expenditure of FNFC Sector by Costs

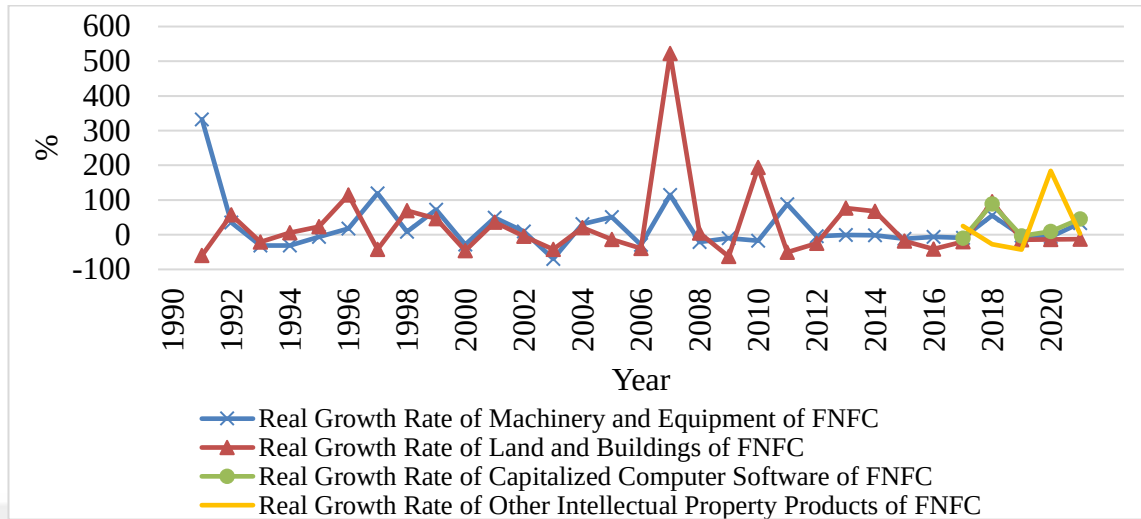
The share of total labor costs decreased during the 1994 and 2001 Economic Crises because total labor costs shrank, and its real growth rate was less than real growth rate of other current costs, which is shown in Figure 30. Moreover, it was the same between 2014 and 2016. Shortly, having more growth rate having more share.

Distribution of capital R&D expenditure of FNFC sector by costs such as machinery and equipment, land and buildings, capitalized computer software, and other intellectual property products can be seen in Figure 31, in other words total capital expenditure is the sum of them. In the last three decades, the share of machinery and equipment R&D expenditure is the highest one in FNFC sector, and the share of land and buildings R&D expenditure is the second highest one except 2016 because after 2016 capitalized computer software R&D expenditure and other intellectual property products R&D expenditure can be viewed. Especially in 2020 and 2021, the share of capitalized computer software R&D expenditure is the second highest one and passed the share of land and buildings. Because capital expenditure is costly and sensitive to instabilities, it is seen that each capital expenditure in detail generally shrank, especially during the crises period more.



Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100.

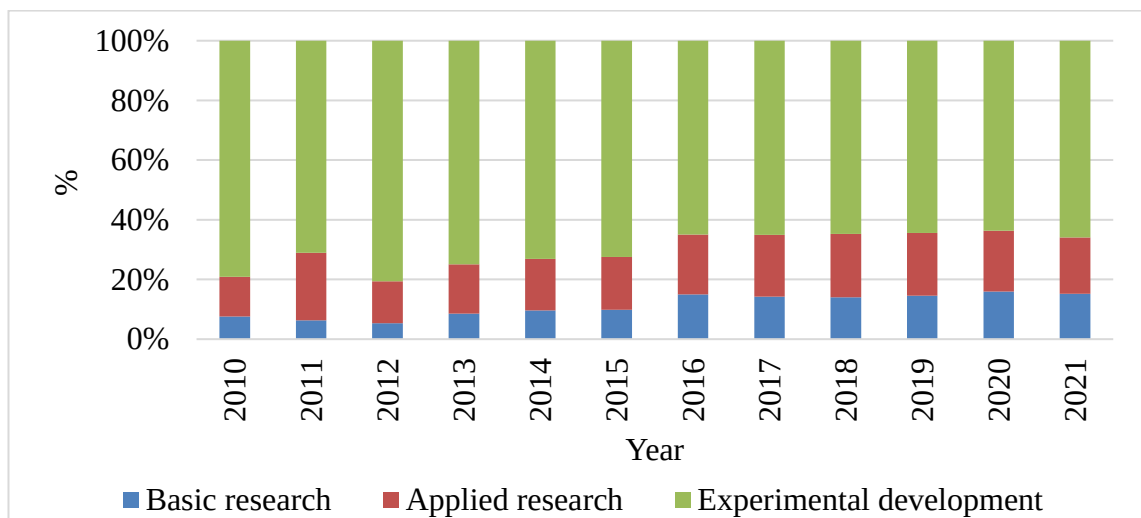
Figure 31: Distribution of Capital Expenditure of FNFC Sector by Costs



Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100.

Figure 32: Real Growth Rate of Capital Expenditure of FNFC Sector by Costs

Distribution of R&D expenditure of FNFC sector by types of R&D such as basic research, applied research, and experimental development can be seen in Figure 33. It is seen that FNFC sector is more experimental development oriented even though the share of R&D expenditure on experimental development decreased in the last decade. The share of R&D expenditure on basic research in FNFC sector is double and the share of R&D expenditure on applied research in FNFC sector is one and a half times more in the last decade.

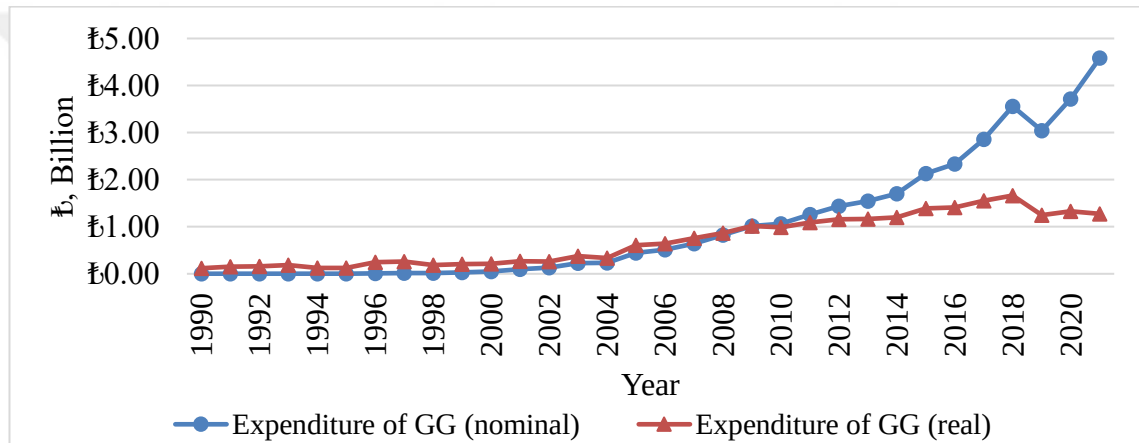


Source: Derived from TURKSTAT Research and Development Activities Survey.

Figure 33: Distribution of R&D Expenditures in FNFC Sector by Types of R&D

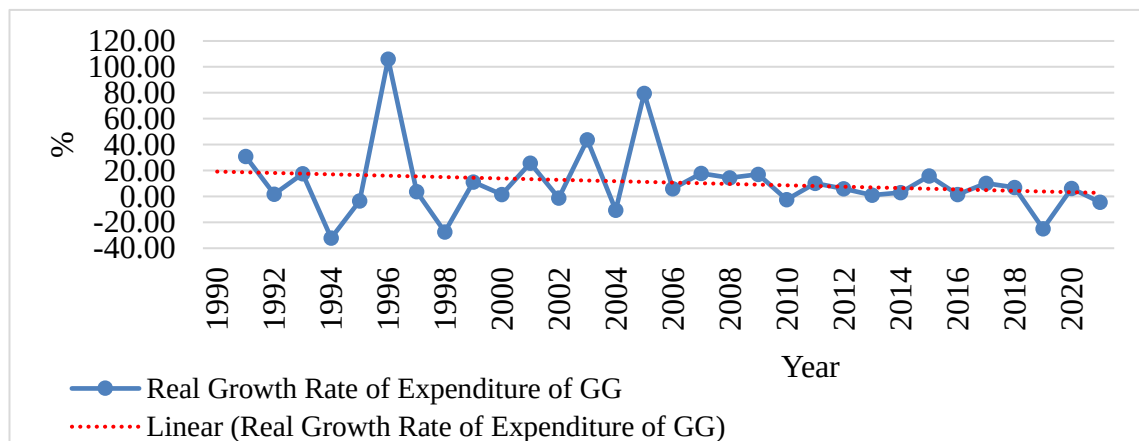
2.2.4.2. R&D Expenditure in General Government (GG) Sector in Detail

Total R&D expenditure of GG Sector in GERD can be seen in Figure 34. *Total R&D expenditure* of GG sector has increased nominally in recent decades in Türkiye, but it has not increased in real terms as much as nominal one because of deflator effect. The real one is not more than ₺2 billion. Moreover, a slowdown of increase in this expenditure as a real term is seen and it decreased in 2019 because of economical instabilities.



Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100. The private non-profit sector has been included in labor costs since 2016.

Figure 34: Total R&D Expenditure of GG Sector in GERD

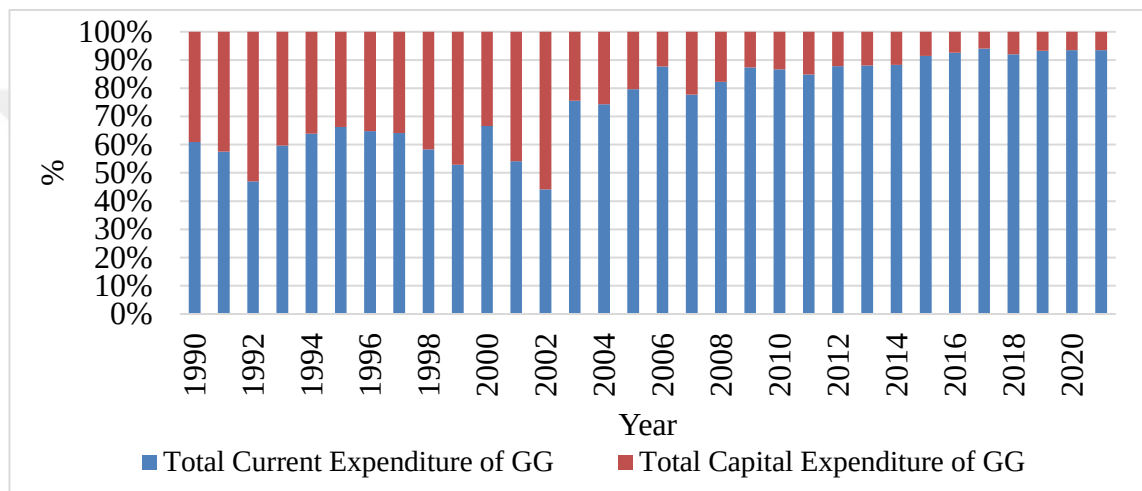


Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100. The private non-profit sector has been included in labor costs since 2016.

Figure 35: Real Growth Rate of Total R&D Expenditure of GG Sector

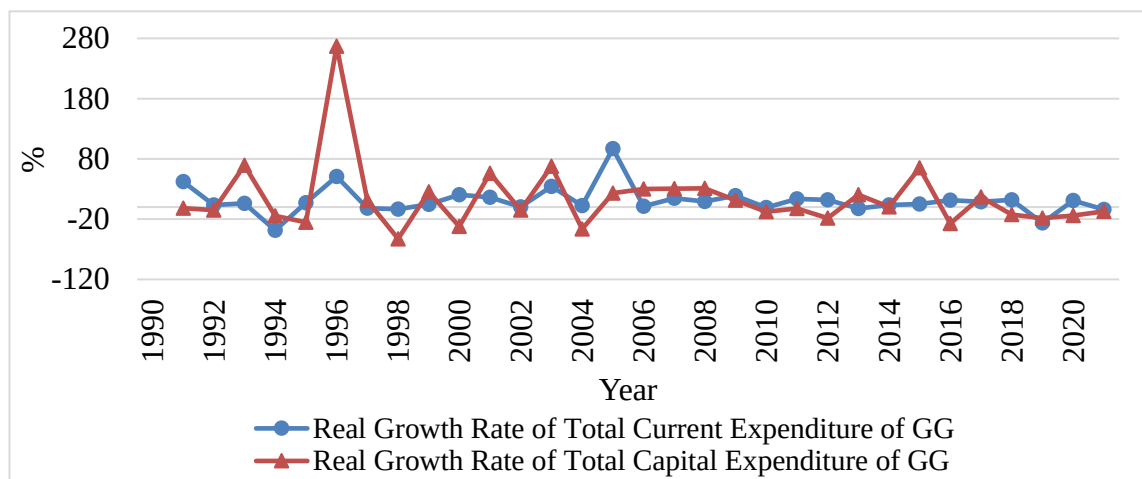
The real growth rate of *total R&D expenditure* of GG sector can be seen in Figure 35. It is seen that the rate decreased linearly from approximately 20% to 0% in the last three decades.

Distribution of *total R&D expenditure* of GG sector by types of expenditure such as total current and total capital expenditures can be seen in Figure 36. The share of total current expenditure increased generally while the share of total capital expenditure decreased in the last three decades.



Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100. The private non-profit sector has been included in labor costs since 2016.

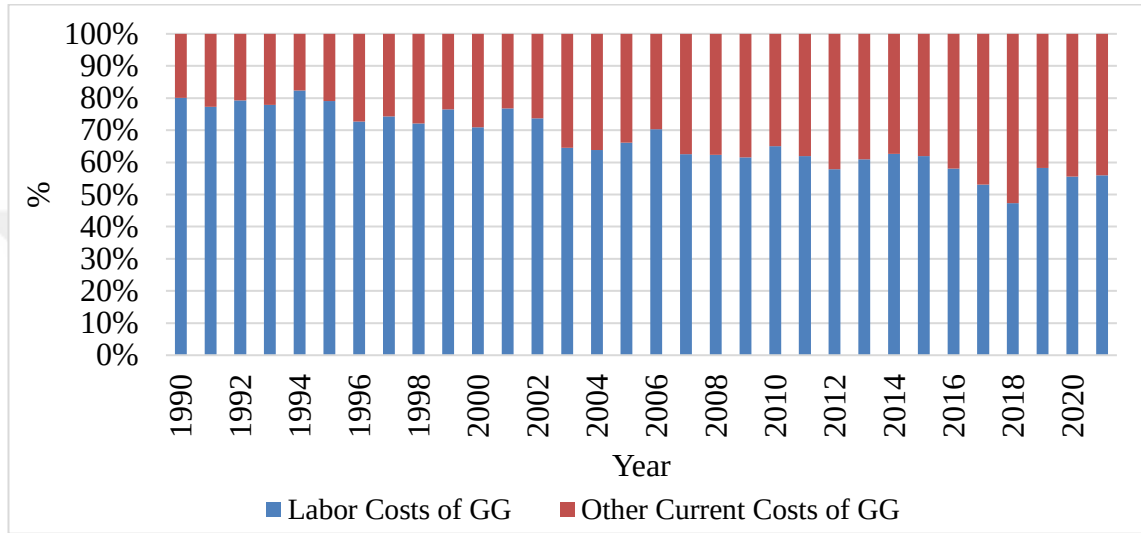
Figure 36: Distribution of Total R&D Expenditure of GG Sector by Types



Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100. The private non-profit sector has been included in labor costs since 2016.

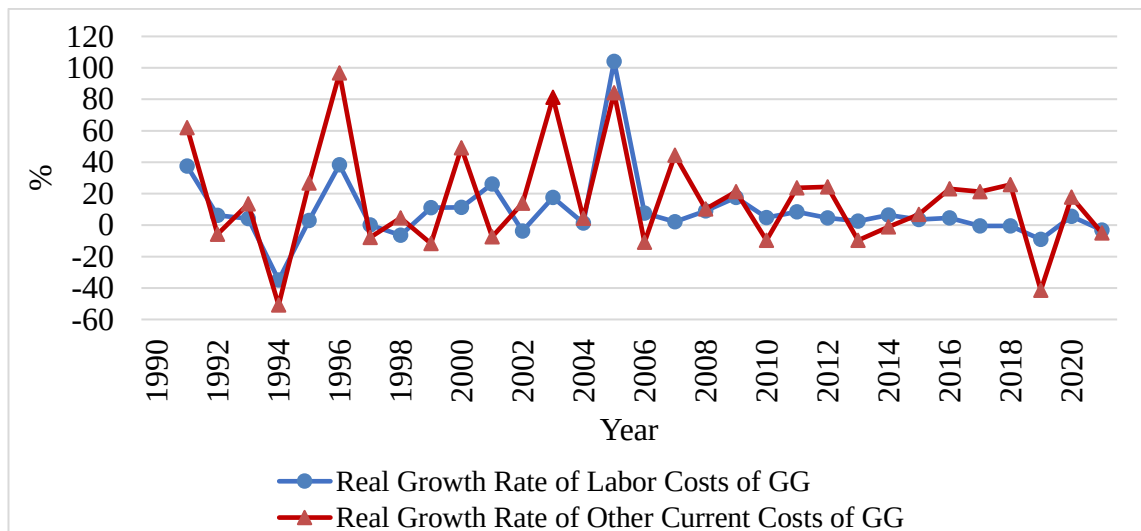
Figure 37: Real Growth Rate of Total R&D Expenditure of GG Sector by Types

Distribution of current R&D expenditure of GG sector by costs such as labor and other current costs can be seen in Figure 38, in other words total current expenditure is the sum of them. In the GG sector, the share of labor costs decreased in the last three decades. Both costs shrank during the economic crises period such as 1994, 1998, and 2008, 2018-2019.



Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100. The private non-profit sector has been included in labor costs since 2016.

Figure 38: Distribution of Current Expenditure of GG Sector by Costs

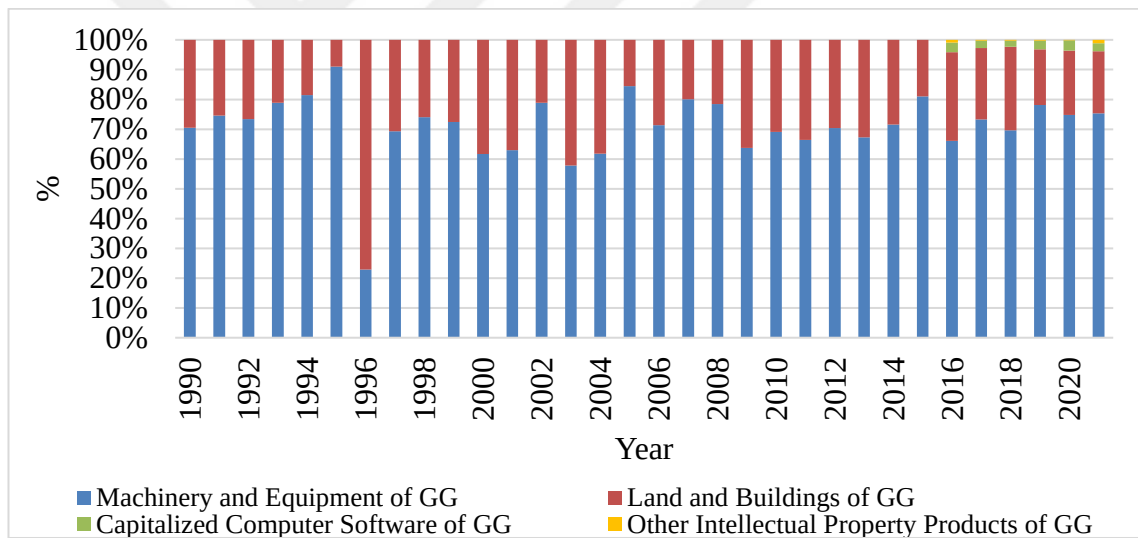


Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100. The private non-profit sector has been included in labor costs since 2016.

Figure 39: Real Growth Rate of Current Expenditure of GG Sector by Costs

The real growth rate of current R&D expenditure of GG sector by costs can be seen in Figure 39. It is seen that the real growth rate of labor costs of GG sector increased after economic crises such as 1994, 1998, and 2001 Economic Crises.

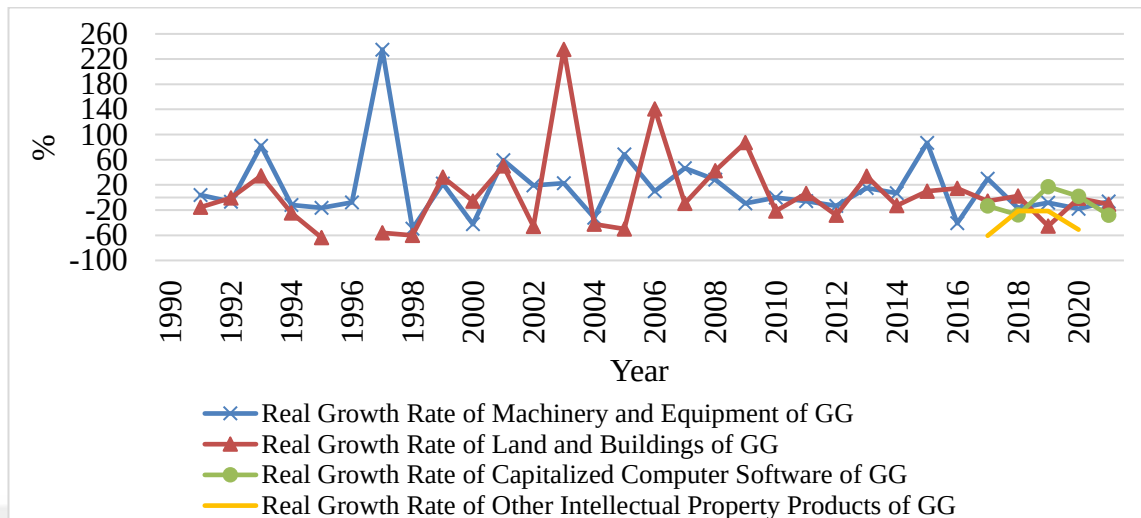
Distribution of capital R&D expenditure of GG sector by costs such as machinery and equipment, land and buildings, capitalized computer software, and other intellectual property products can be seen in Figure 40, in other words total capital expenditure is the sum of them. The share of machinery and equipment R&D expenditure of GG sector is the highest one and generally more than 60%, and the share of land and buildings R&D expenditure is the second highest one. After 2016, it is possible to view the other capital expenditures such as capitalized computer software and other intellectual property products.



Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100.

Figure 40: Distribution of Capital Expenditure of GG Sector by Costs

The growth rate of capital R&D expenditure of GG sector by costs can be seen in Figure 41. It is seen that land and buildings and machinery and equipment R&D expenditure of GG sector shrank most years. The period between 2016 and 2021, all capital expenditures of GG sector shrank generally because of economic and political instabilities, and covid-19 pandemic.

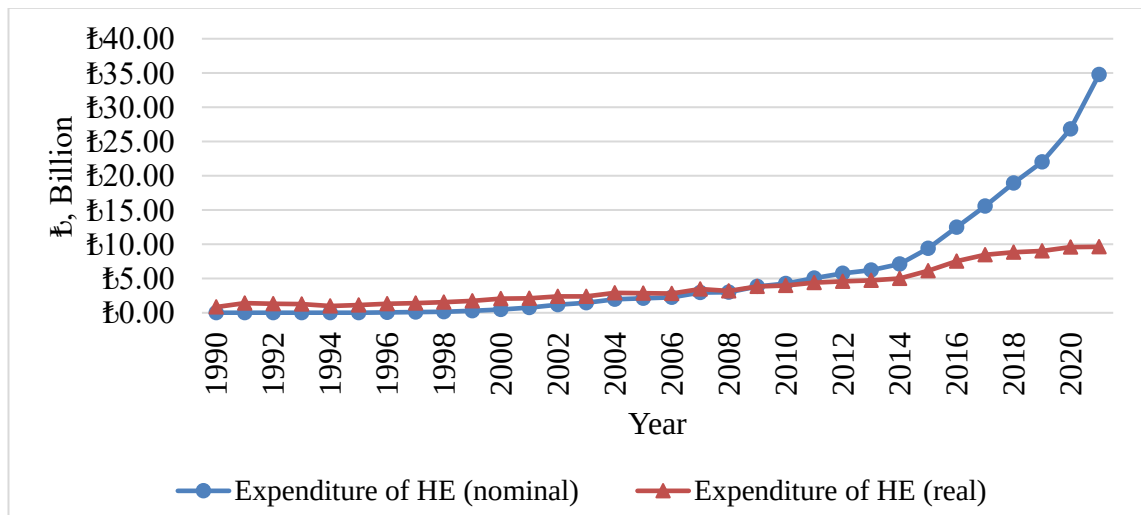


Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100. Because of the real growth rate of land and buildings R&D expenditure in 1996 is too high (3053.83%) and the real growth rate of other intellectual property products R&D expenditure in 2021 is too high (647.03%) they are eliminated from the figure to view the others' growth rate with better scale.

Figure 41: Real Growth Rate of Capital Expenditure of GG Sector by Costs

2.2.4.3. R&D Expenditure in Higher Education (HE) Sector in Detail

Total R&D expenditure of HE Sector in GERD can be seen in Figure 42. Total R&D expenditure of HE sector has increased nominally in recent decades in Türkiye, but it has not increased in real terms as much as nominal one because of deflator effect.

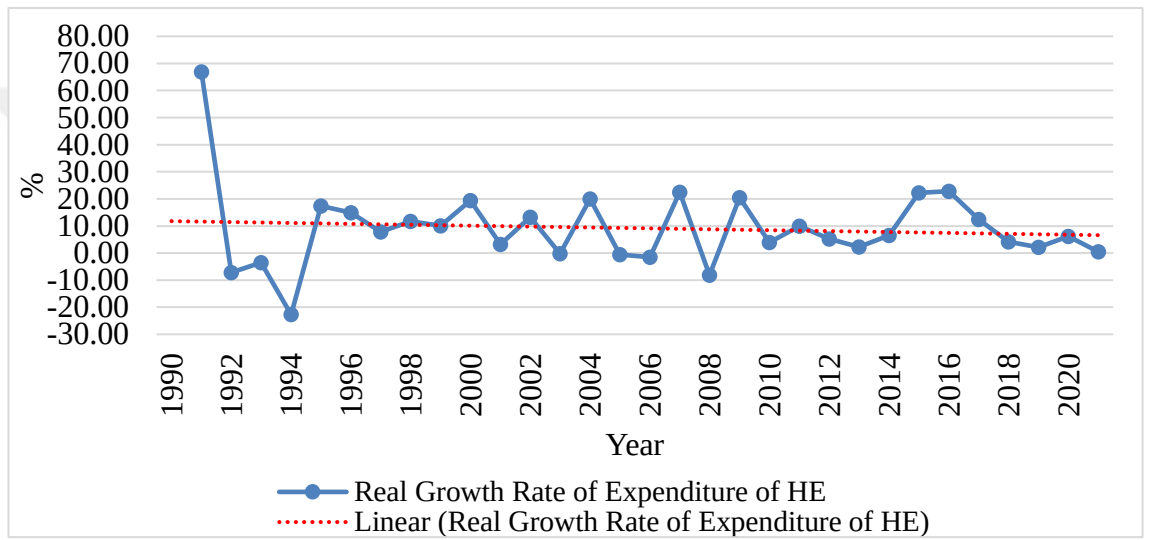


Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100. The private non-profit sector has been included in labor costs since 2016.

Figure 42: Total R&D Expenditure of HE Sector in GERD

The real *total R&D expenditure* of HE Sector is not more than ₺10 billion in the last three decades. Moreover, a slowdown of increase in this expenditure as a real term is seen.

The real growth rate of *total R&D expenditure* of HE sector can be seen in Figure 43. It is seen that the rate decreased linearly from approximately 12% to 8% in the last three decades. The *total R&D expenditure* of HE sector shrank, especially during the 1994 and 2001 Economic Crises.

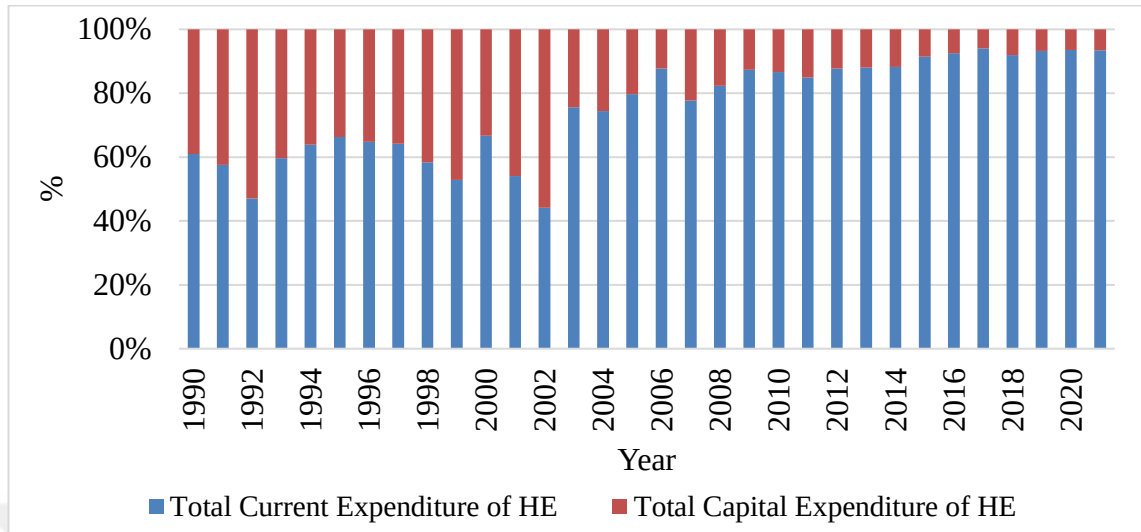


Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100. The private non-profit sector has been included in labor costs since 2016.

Figure 43: Real Growth Rate of Total R&D Expenditure of HE Sector in GERD

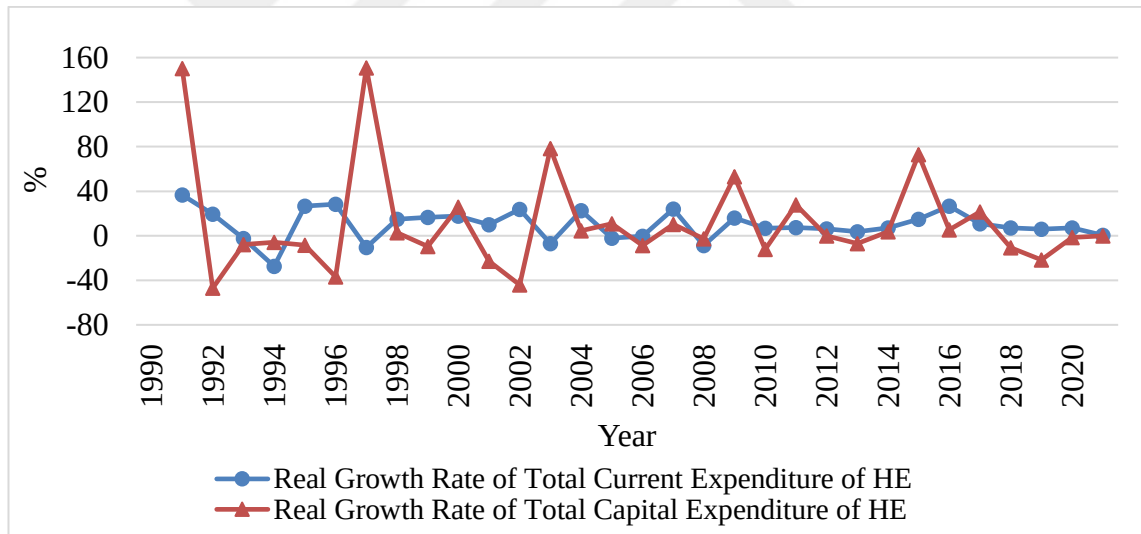
Distribution of *total R&D expenditure* of HE sector by types of expenditure such as total current and total capital expenditures can be seen in Figure 44. The share of total current expenditure increased generally while the share of total capital expenditure decreased in the last three decades. The share of total current expenditure decreased after the 1994 and 2001 Economic Crises.

The real growth rate of *total R&D expenditure* of HE sector by types of expenditure can be seen in Figure 45. Total capital expenditure of HE sector shrank most years while the growth rate of total current expenditure of HE sector is less than 10% in recent years.



Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100. The private non-profit sector has been included in labor costs since 2016.

Figure 44: Distribution of Total R&D Expenditure of HE Sector by Types

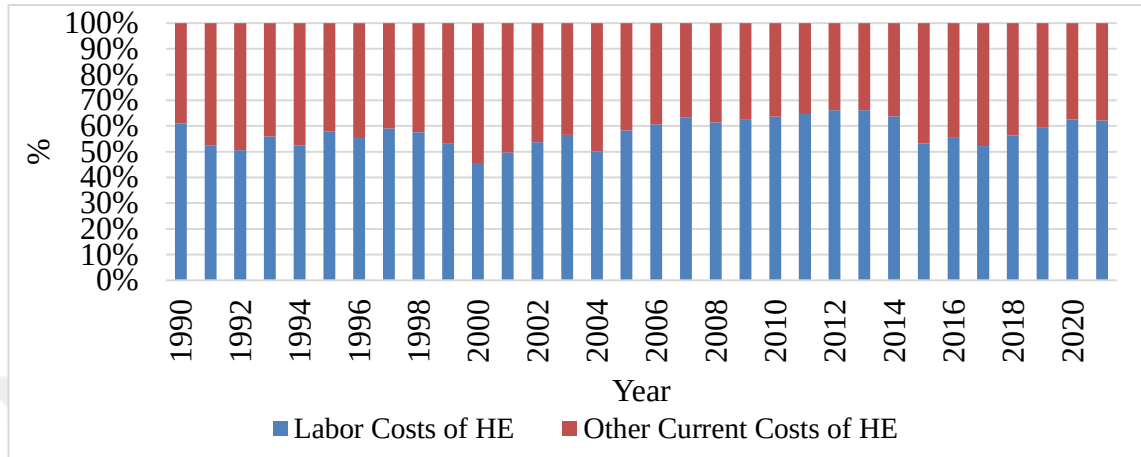


Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100. The private non-profit sector has been included in labor costs since 2016.

Figure 45: Real Growth Rate of Total R&D Expenditure of HE Sector by Types

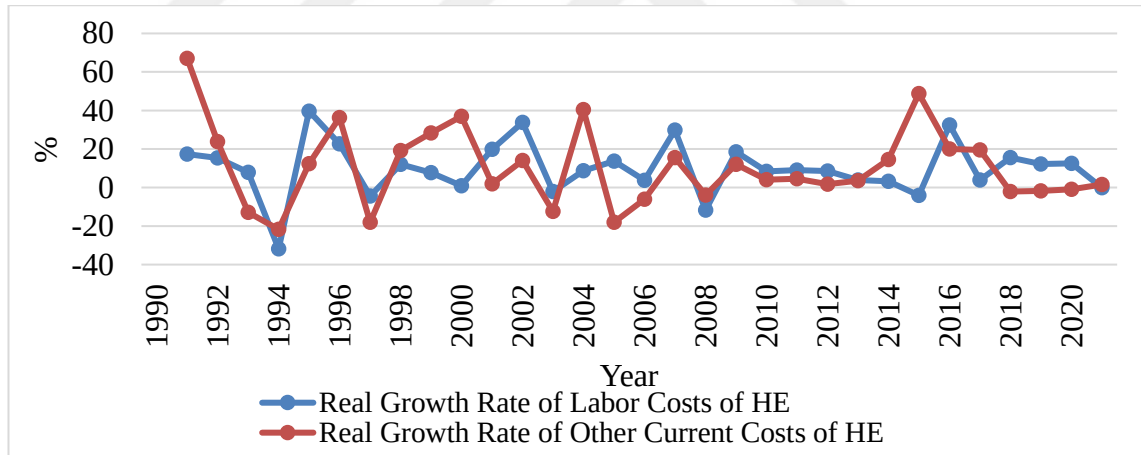
Distribution of current R&D expenditure of HE sector by costs such as labor and other current costs can be seen in Figure 46, in other words total current expenditure is the sum of them. In the HE sector, the share of labor costs is generally more than 50%. Both costs shrank during the economic crises period such as 1994,

1998, and 2008, 2018-2019. Moreover, the real growth rate of current R&D expenditure of HE sector by costs can be seen in Figure 47.



Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100. The private non-profit sector has been included in labor costs since 2016.

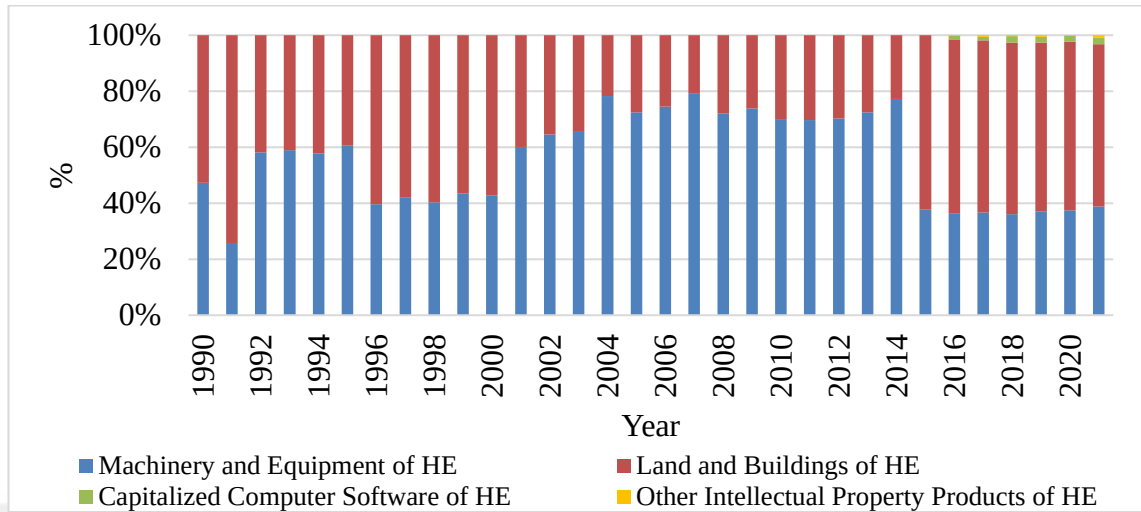
Figure 46: Distribution of Current Expenditure of HE Sector by Costs



Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100. The private non-profit sector has been included in labor costs since 2016.

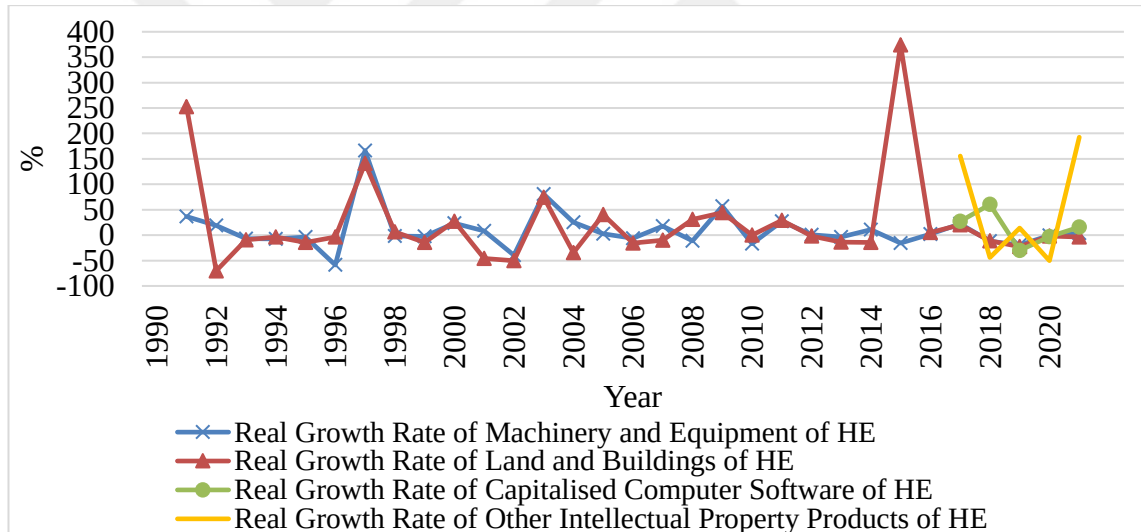
Figure 47: Real Growth Rate of Current Expenditure of HE Sector by Costs

Distribution of capital R&D expenditure of HE sector by costs such as machinery and equipment, land and buildings, capitalized computer software, and other intellectual property products can be seen in Figure 48, in other words total capital expenditure is the sum of them.



Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100.

Figure 48: Distribution of Capital Expenditure of HE Sector by Costs



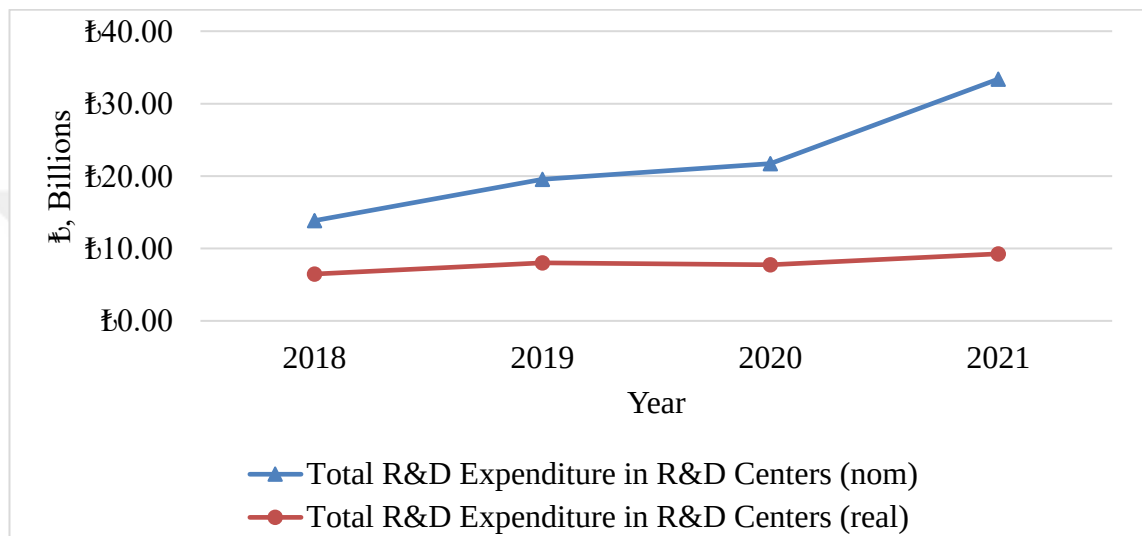
Source: Derived from TURKSTAT Research and Development Activities Survey, and World Bank GDP Deflator Linked Series of Türkiye because of available data until 1990, 2009=100. The private non-profit sector has been included in labor costs since 2016.

Figure 49: Distribution of Capital Expenditure of HE Sector by Costs

The share of machinery and equipment R&D expenditure of HE sector is approximately more than 60%, and the highest one after 2000 until 2014. It is approximately 40% in recent years because of the increase in the land and buildings expenditures in 2015. Moreover, these expenditures shrank generally in the last three decades because of economic and political instabilities, which is shown in Figure 49.

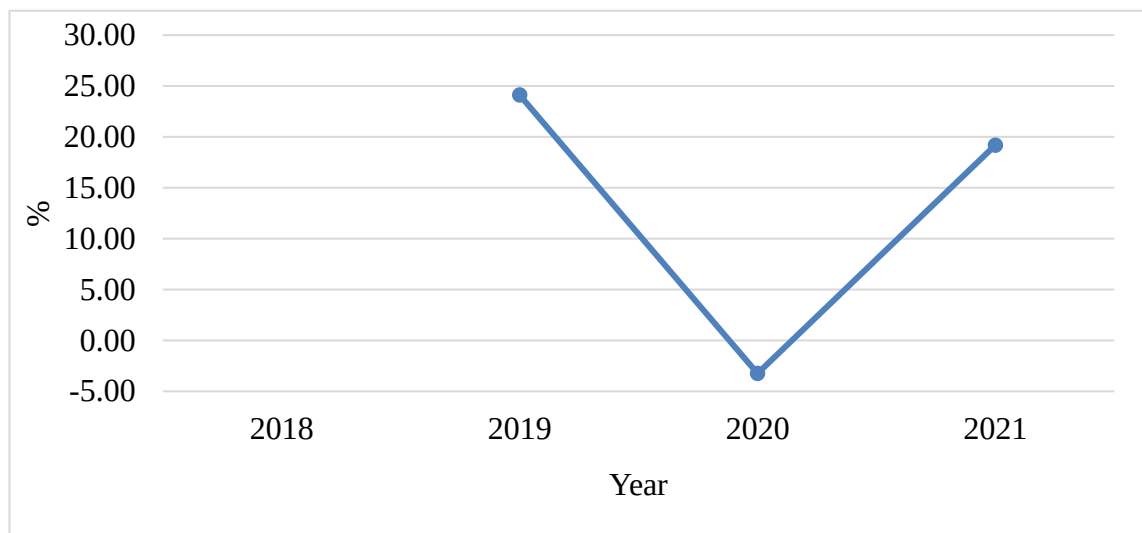
2.2.5. R&D Expenditure in R&D Centers by Firm Size

R&D centers in Türkiye can be viewed since 2018 because of data availability. *Total R&D expenditure* in R&D centers in Türkiye has increased slightly in real terms, approximately from ₺6.4 billion in 2018 to ₺9.4 billion in 2021, which is shown in Figure 50.



Source: Derived from TURKSTAT Research and Development Activities Survey.

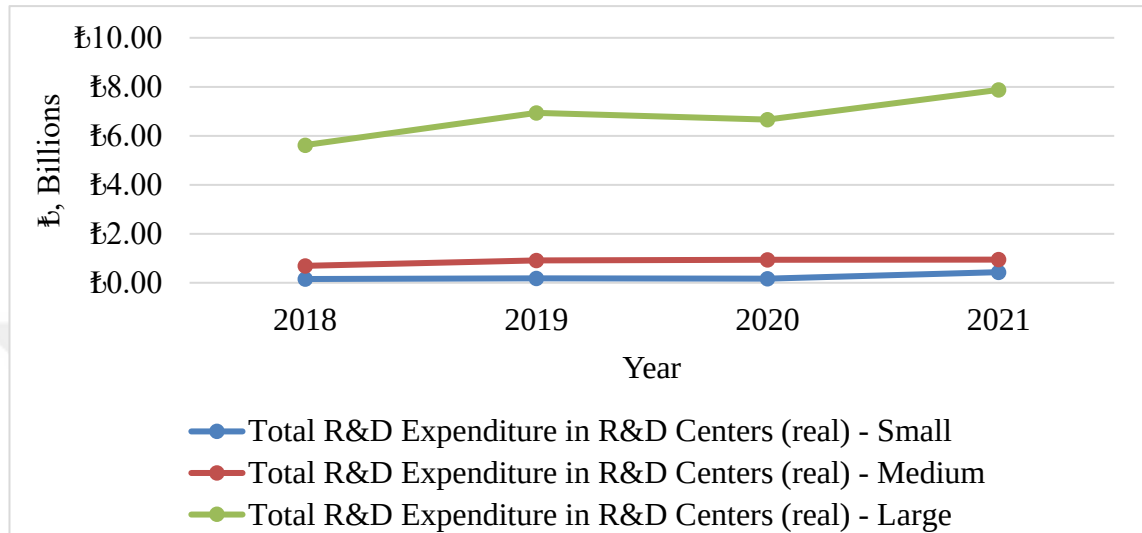
Figure 50: Total R&D Expenditures in R&D Centers (2018-2021)



Source: Derived from TURKSTAT Research and Development Activities Survey.

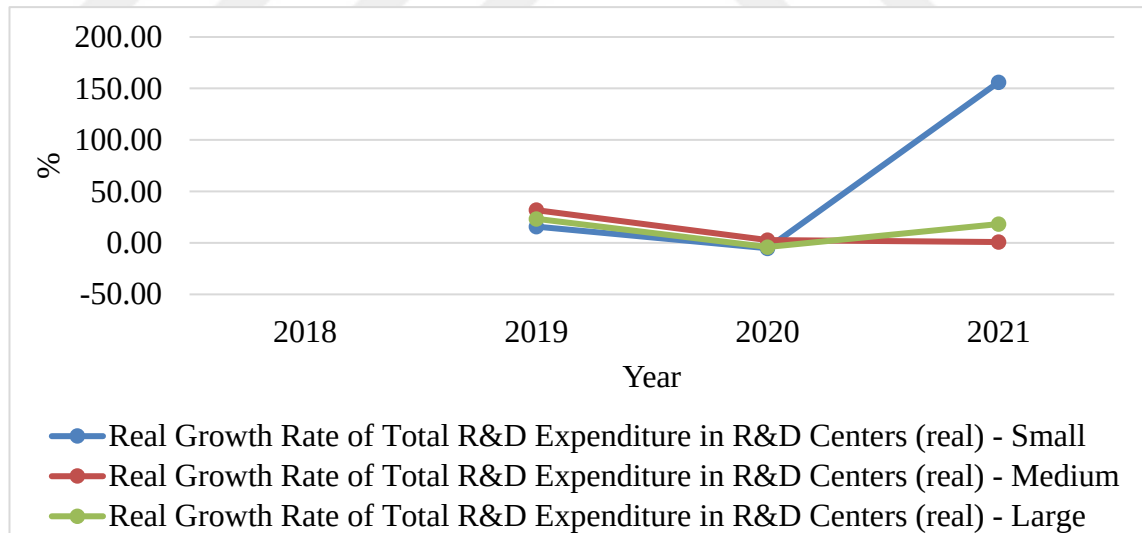
Figure 51: Real Growth Rate of Total R&D Expenditure in R&D Centers (2018-2021)

The growth rate of *total R&D expenditure* in R&D centers is approximately 24% in 2019 and decreased in 2020 because of shrinkage of the expenditure in real terms in the shadow of 2018-2019 Economic Crisis and covid-19 pandemic.



Source: Derived from TURKSTAT Research and Development Activities Survey.

Figure 52: Total R&D Expenditures in R&D Centers by Firm Size (2018-2021)



Source: Derived from TURKSTAT Research and Development Activities Survey.

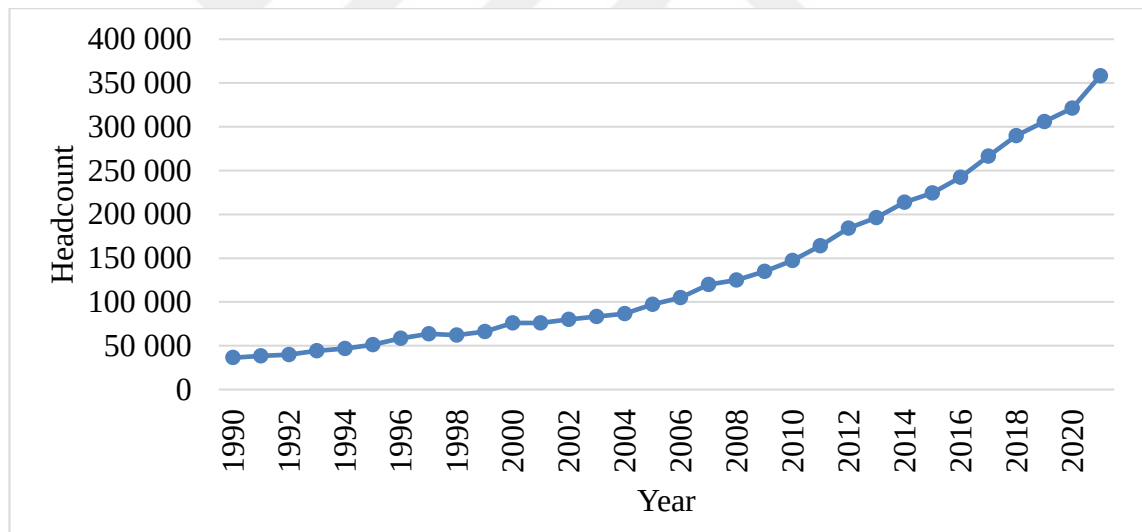
Figure 53: Real Growth Rate of Total R&D Expenditures in R&D Centers by Firm Size (2018-2021)

Real *total R&D expenditure* in R&D centers can be viewed by firm size, which is shown in Figure 52. *Total R&D expenditure* in R&D centers of small firm is generally less than 500 million in real terms and is the lowest one. This expenditure

of medium firm is generally between ₺500 million and ₺1 billion. The highest one is the R&D expenditure of large firm and is generally between ₺6 and ₺8 billion, in other words the share of *total R&D expenditure* in R&D centers of large firm is more than %80. It seems like large firms tend to spend more on R&D activities in R&D centers in Türkiye, in other words being a larger firm is a kind of advantage to be able to spend more on R&D.

2.2.6. R&D Personnel by R&D Sectors and Occupation

R&D personnel is necessary to conduct R&D activities. Türkiye put emphasis on this issue more decade by decade that highlighted many times in 5YDPs. The number (headcount) of R&D personnel in Türkiye, which is shown in Figure 54, has increased in the last three decades approximately from 36.000 in 1990 to 358.000 in 2021.

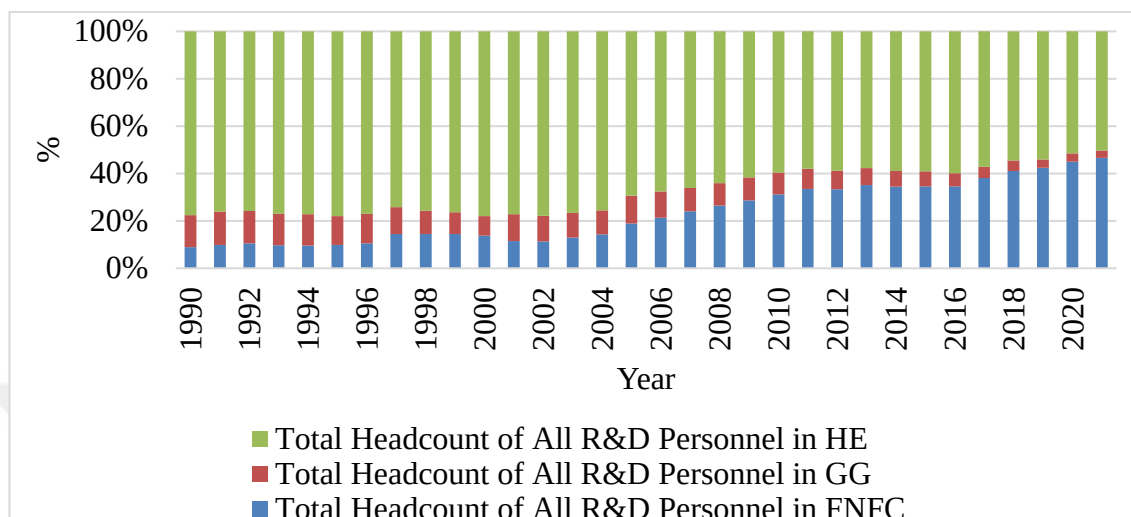


Source: Derived from TURKSTAT Research and Development Activities Survey. The private non-profit sector has been included in labor costs since 2016.

Figure 54: Total Headcount of All R&D Personnel (1990-2021)

Distribution of total number of all R&D personnel by sector can be seen in Figure 55. The share of total number of all R&D personnel of HE sector is the highest one and especially after the 2001 Economic Crisis it started to decrease because the number of R&D personnel increased faster in FNFC sector. It seems like many R&D personnel passed from GG sector to FNFC sector, and new R&D personnel generally may prefer FNFC sector. In other words, the share of total number of all R&D

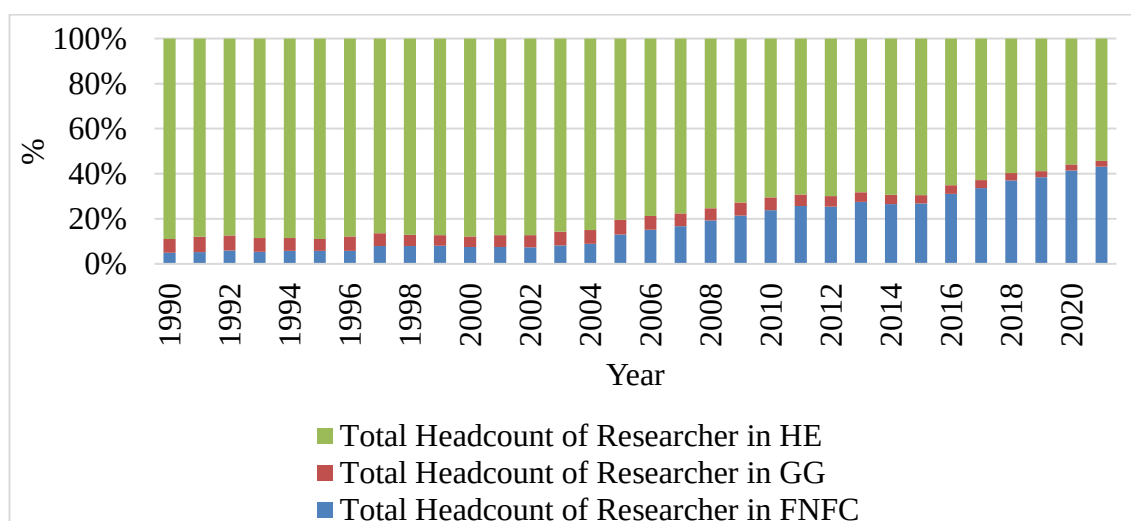
personnel of FNFC sector increased clearly in the 2000s and 2010s while the share of it of GG sector decreased.



Source: Derived from TURKSTAT Research and Development Activities Survey. The private non-profit sector has been included in labor costs since 2016.

Figure 55: Distribution of Total Headcount of All R&D Personnel by Sector (1990-2021)

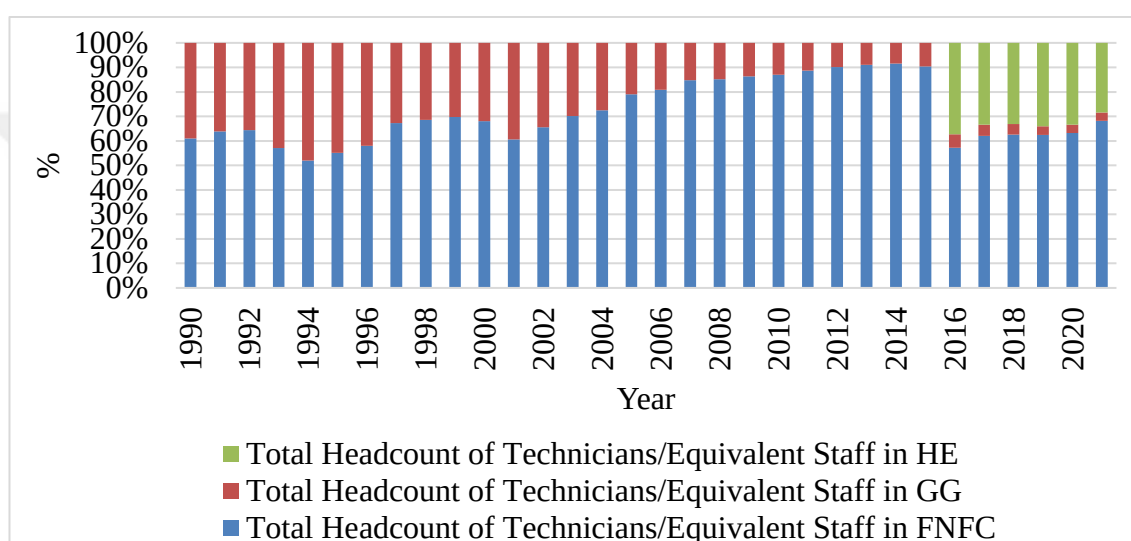
R&D personnel comprises researcher, technicians/equivalent staff, and other supporting staff. Researchers are significant to conduct R&D. Technicians/equivalent staff and other supporting staff are technical and supportive power respectively behind researchers.



Source: Derived from TURKSTAT Research and Development Activities Survey. The private non-profit sector has been included in labor costs since 2016.

Figure 56: Distribution of Total Headcount of Researcher by Sector (1990-2021)

Distribution of total number of researchers by sector can be viewed in Figure 56. The share of total number of researchers of HE sector is the highest one and generally more than 80% until 2005 but decreased after that year, approximately 58% in 2021. The share of total number of researchers of GG sector is the lowest one and decreased year by year after 2000. However, the share of total number of researchers of FNFC sector increased rapidly because researchers may prefer FNFC sector more year by year.



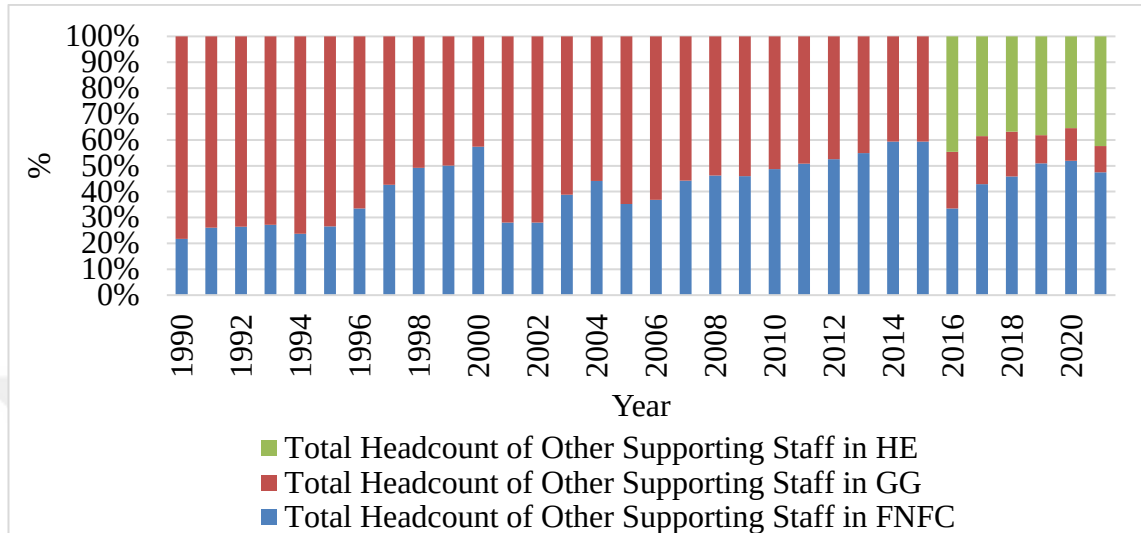
Source: Derived from TURKSTAT Research and Development Activities Survey. The private non-profit sector has been included in labor costs since 2016.

Figure 57: Distribution of Total Headcount of Technicians/Equivalent Staff by Sector (1990-2021)

Distribution of total number of technicians/equivalent staff by sector can be viewed in Figure 57. The share of total number of technicians/equivalent staff of HE sector can be viewed since 2016 and almost decreased. The share of total number of technicians/equivalent staff of FNFC sector is the highest one and generally increased except during the 1994 and 2001 Economic Crises while the share of total number of technicians/equivalent staff of GG sector generally decreased.

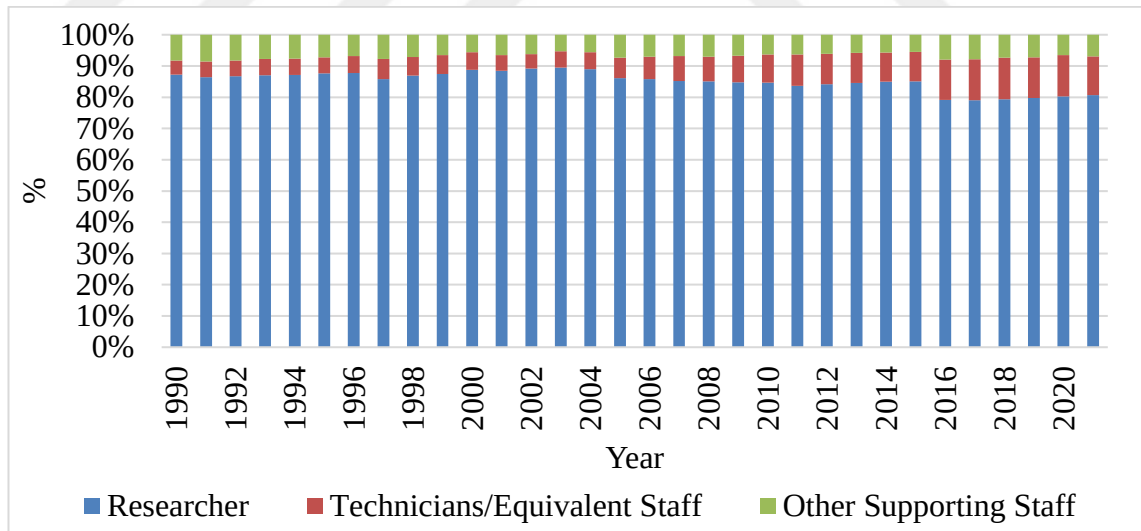
Distribution of total number of other supporting staff by sector can be viewed in Figure 58. The share of total number of other supporting staff of HE sector can be viewed since 2016 and approximately 40% on average. The share of total number of other supporting staff of FNFC sector is generally increased except during the 1994

and 2001 Economic Crises while the share of total number of other supporting staff of GG sector generally decreased.



Source: Derived from TURKSTAT Research and Development Activities Survey. The private non-profit sector has been included in labor costs since 2016.

Figure 58: Distribution of Total Headcount of Other Supporting Staff by Sector (1990-2021)

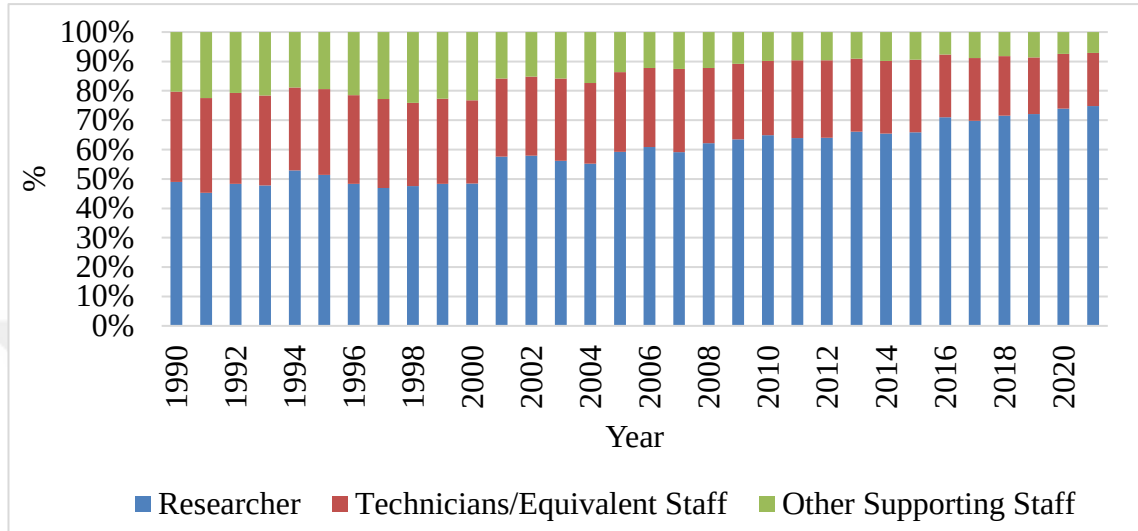


Source: Derived from TURKSTAT Research and Development Activities Survey. The private non-profit sector has been included in labor costs since 2016.

Figure 59: Distribution of Total Headcount of R&D Personnel by Occupation (1990-2021)

Distribution of total number of all R&D personnel by occupation in Türkiye can be seen in Figure 59. The share of total number of researchers in total number of

R&D personnel in Türkiye is the highest one and it started to decrease especially after the 2001 Economic Crisis because the number of technicians/equivalent staff other supporting staff increased faster.

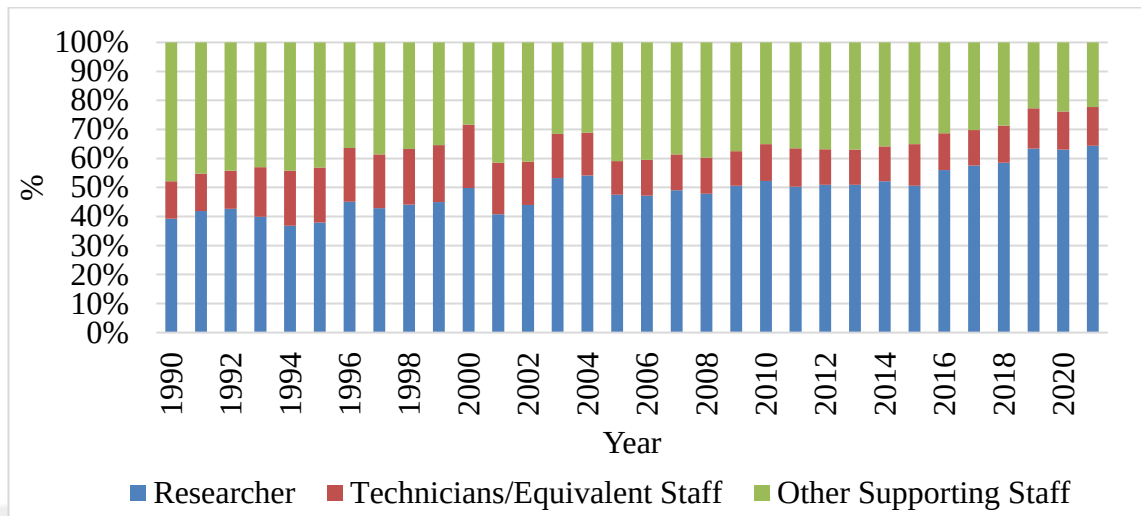


Source: Derived from TURKSTAT Research and Development Activities Survey. The private non-profit sector has been included in labor costs since 2016.

Figure 60: Distribution of Total Headcount of R&D Personnel by Occupation in FNFC Sector (1990-2021)

In the FNFC sector, distribution of total number of all R&D personnel by occupation can be seen in Figure 60. The share of total number of researchers is the highest one (approximately 70% after 2015) and generally increased in the last three decades while the share of the total number of technicians/equivalent staff and other supporting staff generally decreased. The headcount of researchers in FNFC sector is 125.000 approximately in 2021.

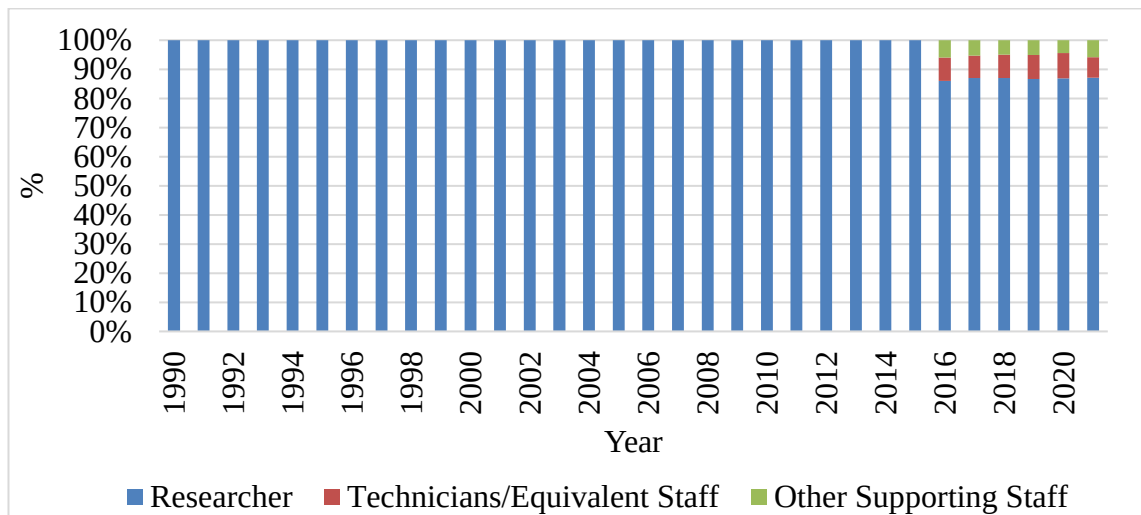
In the GG sector, distribution of total number of all R&D personnel by occupation can be seen in Figure 61. The share of total number of researchers is generally more than 40% and passed 60% in 2019, and it is the highest one since the 2001 Economic Crisis. The share of the total number of other supporting staff generally decreased. The headcount of researchers in GG sector is 7300 approximately in 2021.



Source: Derived from TURKSTAT Research and Development Activities Survey. The private non-profit sector has been included in labor costs since 2016.

Figure 61: Distribution of Total Headcount of R&D Personnel by Occupation in GG Sector (1990-2021)

In the HE sector, distribution of total number of all R&D personnel by occupation can be seen in Figure 62. All R&D personnel were researchers until 2016. After that year, data about technicians/equivalent staff and other supporting staff can be viewed so the share of total number of researchers decreased but more than 80%. The total number of researchers in HE sector is 157.000 approximately in 2021.

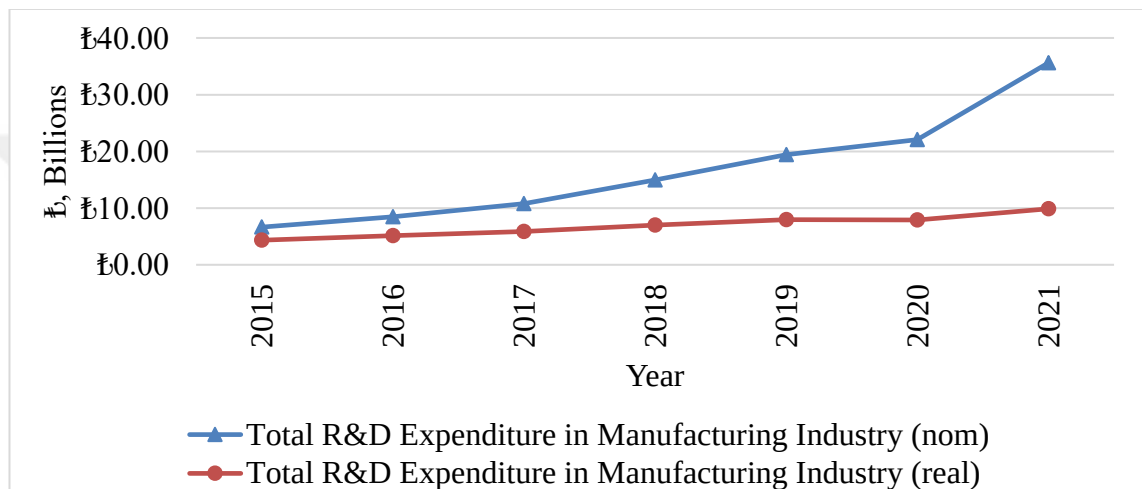


Source: Derived from TURKSTAT Research and Development Activities Survey. The private non-profit sector has been included in labor costs since 2016.

Figure 62: Distribution of Total Headcount of R&D Personnel by Occupation in HE Sector (1990-2021)

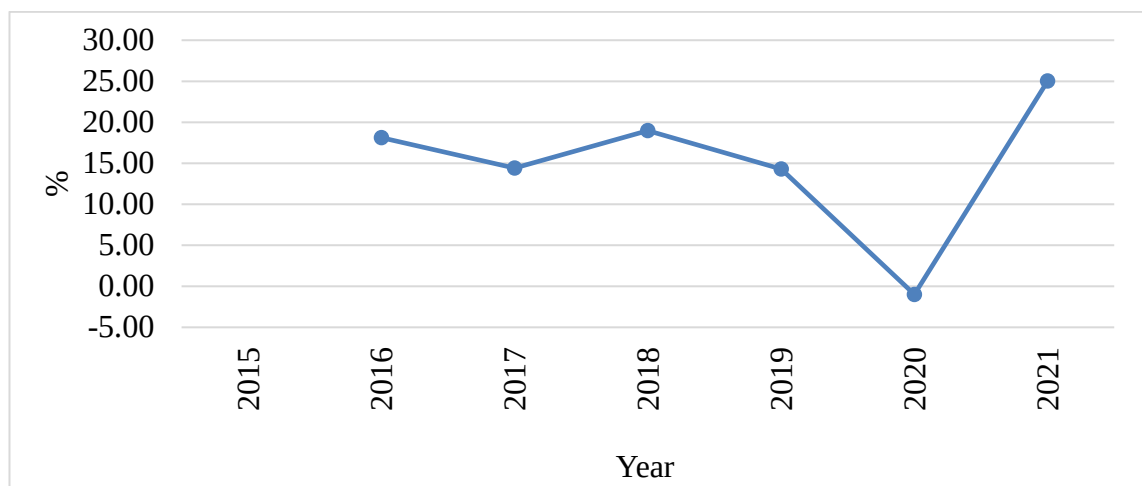
2.2.7. R&D Statistics of Turkish Manufacturing Industry

Total R&D expenditure in Turkish manufacturing industry can be seen in Figure 63 since 2015 because of data availability. It has increased nominally in recent decades, but it has not increased in real terms as much as nominal one because of deflator effect. *Total R&D expenditure* in Turkish manufacturing industry is not more than ₺10 billion in real terms since 2015.



Source: Derived from TURKSTAT Research and Development Activities Survey. The private non-profit sector has been included in labor costs since 2016.

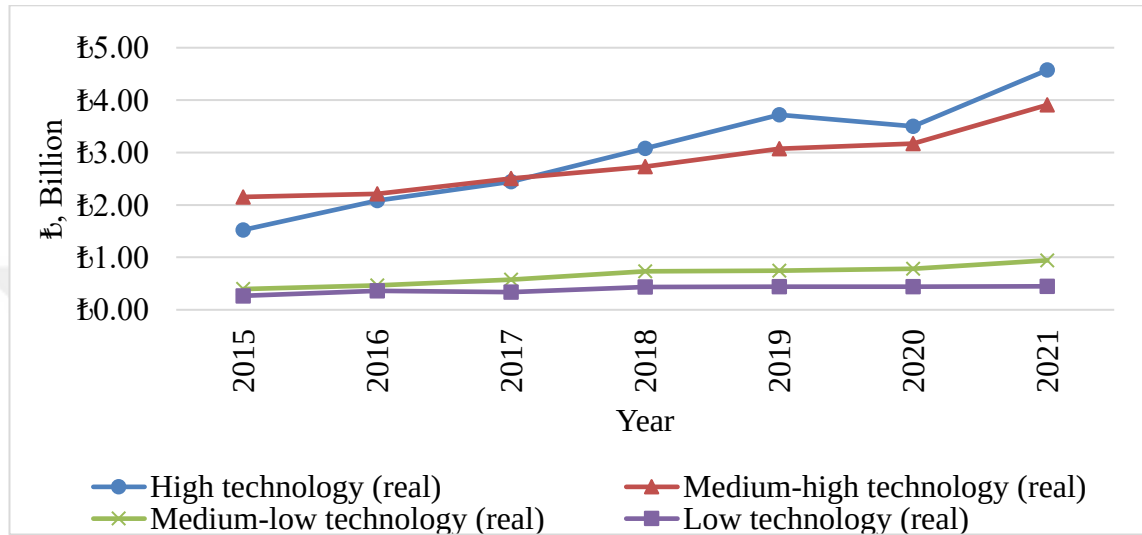
Figure 63: Total R&D Expenditure in Turkish Manufacturing Industry (2015-2021)



Source: Derived from TURKSTAT Research and Development Activities Survey. The private non-profit sector has been included in labor costs since 2016.

Figure 64: Real Growth Rate of Total R&D Expenditure in Manufacturing Industry (2016-2021)

The real growth rate of *total R&D expenditure* in Turkish manufacturing industry can be seen in Figure 64. *Total R&D expenditure* in Turkish manufacturing industry shrank in 2020 because of covid-19 pandemic and the growth rate of it is 18% on average approximately.

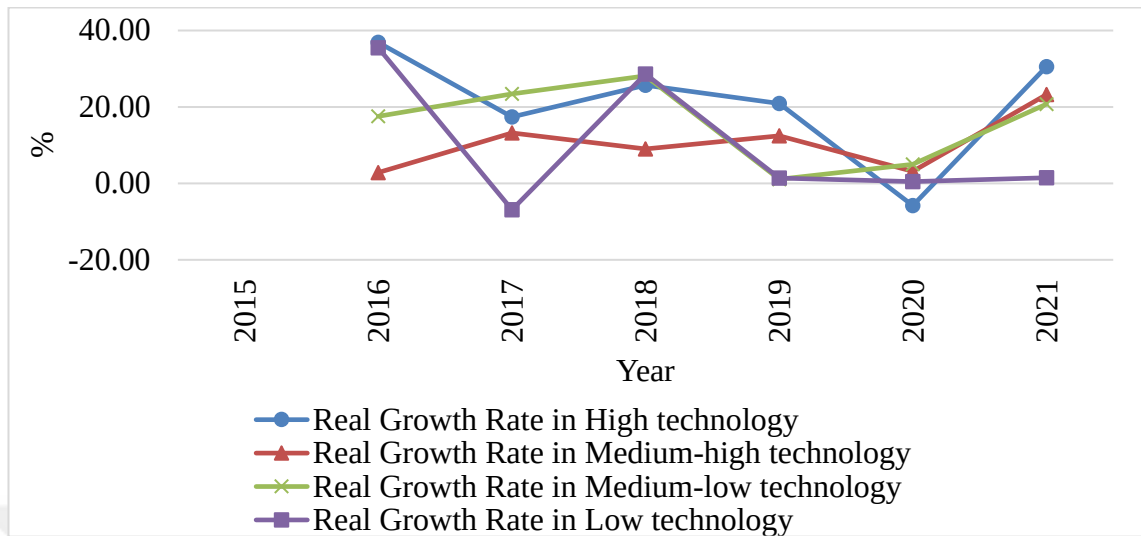


Source: Derived from TURKSTAT Research and Development Activities Survey. The private non-profit sector has been included in labor costs since 2016.

Figure 65: Real R&D Expenditure in Manufacturing Industry by Technology Level (2015-2021)

The real *total R&D expenditure* in Turkish manufacturing industry can be seen by technology level in Figure 65. It is seen that the expenditure on high tech and medium-high tech increased rapidly and ₺8.4 billion approximately in 2021 while the expenditure on the others increased slightly and ₺1.4 billion approximately in 2021.

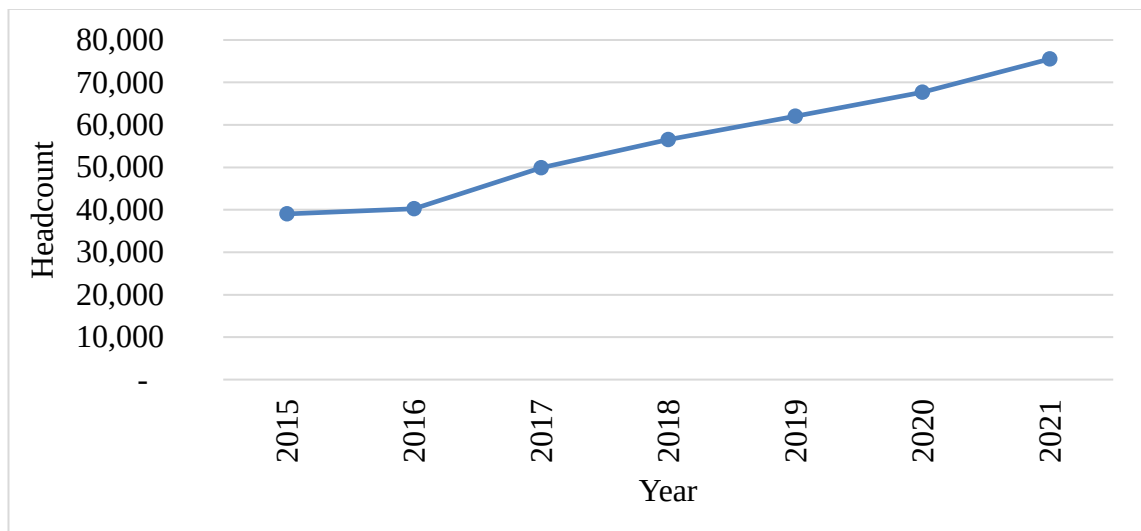
Moreover, the real growth rate of R&D expenditure in Turkish manufacturing industry can be seen by technology level in Figure 66. The real growth rate of R&D expenditure on high tech, medium-high tech, and low tech decreased after 2018 because of economic instabilities and covid-19 in 2020. The growth rate of all R&D expenditures decreased in 2020 except the rate in medium-low tech. This decrease was so deep for high tech, moderate for medium-high, and slightly for low tech, in other words covid-19 pandemic may affect high tech more.



Source: Derived from TURKSTAT Research and Development Activities Survey. The private non-profit sector has been included in labor costs since 2016.

Figure 66: Real Growth Rate of R&D Expenditure in Manufacturing Industry by Technology Level (2016-2021)

Total headcount of R&D personnel in Turkish manufacturing industry can be seen in Figure 67. The headcount of R&D personnel in the manufacturing industry increased from approximately 39.000 in 2015 to approximately 80.000 in 2021.

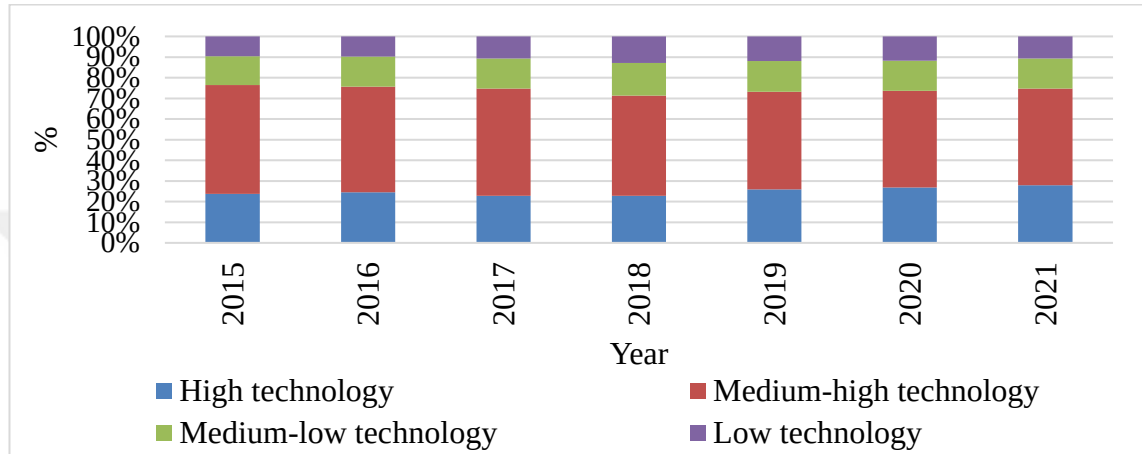


Source: Derived from TURKSTAT Research and Development Activities Survey.

Figure 67: Total R&D Personnel in Manufacturing Industry (2015-2021)

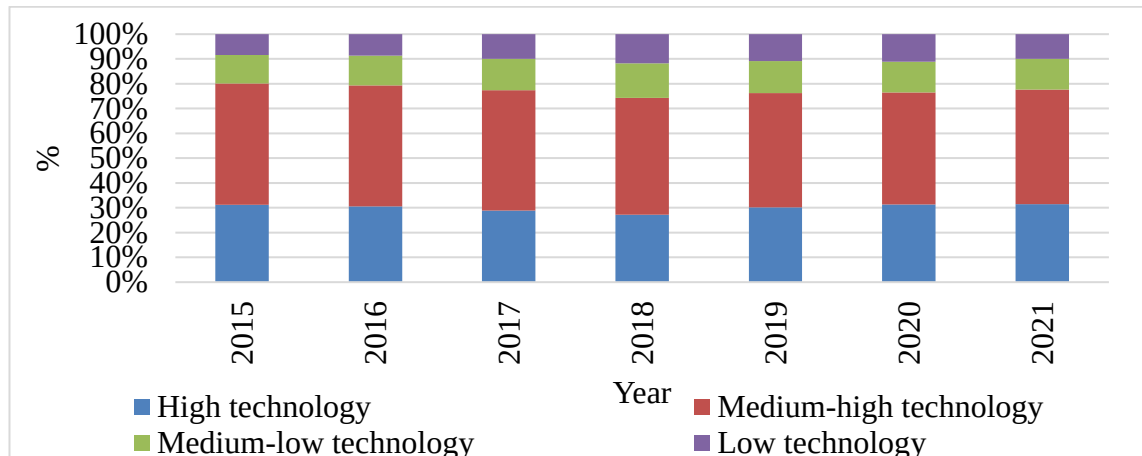
It is important to check distribution of R&D personnel by technology level. Distribution of total R&D personnel in manufacturing industry by technology level can be seen in Figure 68. The highest share of R&D personnel works in medium-high

tech manufacturing industries and the second highest share of them works in high tech manufacturing industries. In other words, approximately 75% of R&D personnel work in the high tech and medium-high tech manufacturing industries. Almost 15% of them work in the medium-low tech industries and the rest of them work in the low-tech industries.



Source: Derived from TURKSTAT Research and Development Activities Survey.

Figure 68: Distribution of Total R&D Personnel in Manufacturing Industry by Technology Level (2015-2021)



Source: Derived from TURKSTAT Research and Development Activities Survey.

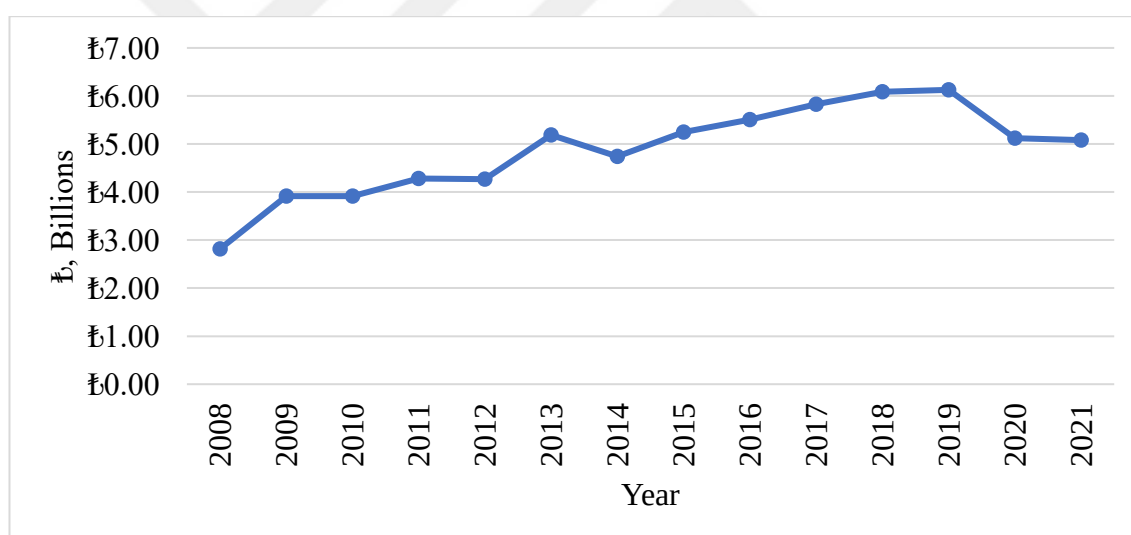
Figure 69: Distribution of Researcher in Manufacturing Industry by Technology Level (2015-2021)

Researchers are the most important personnel in all R&D personnel to conduct R&D activities. Distribution of researchers in the manufacturing industry by technology level can be seen in Figure 69. It is seen clearly that researchers work in

medium-high tech manufacturing industries primarily, and in the high-tech industries secondarily. Most of them, 78% of them approximately, work in these both industries. The rest of them, 22% of them approximately, work in the medium-low tech and low-tech industries.

2.2.8. Total Central Government Budget Appropriations and Outlays on R&D by Socio-Economic Objectives

Total central government budget appropriations and outlays on R&D is not more than ₺6.2 billion in real terms, which is seen in Figure 70. Increase in the budget slowed down especially after 2015 and the budget decreased from approximately ₺6 billion in 2019 to ₺5 billion in 2020 in real terms because of economic and political instabilities and covid-19 pandemic.



Source: TURKSTAT, Central Government Budget Appropriations and Outlays on R&D, 2021. Calculations are based on initial appropriations for 2021 and actual outlays for 2020.

Figure 70: Total Central Government Budget Appropriations and Outlays on R&D by Socio-Economic Objectives

Distribution of central government budget appropriations and outlays on R&D, which is seen in Table 1, is significant to understand tendency of central government by socio-economic objectives such as general advancement of knowledge (R&D financed from general university funds—GUF), defense, industrial production and technology, transport, telecommunication and other infrastructures, education, general advancement of knowledge (R&D financed from other sources than GUF), agriculture,

health, exploration and exploitation of the earth, energy, exploration and exploitation of space, environment, political and social Systems, structures and processes, culture, recreation, religion and mass media.

Table 1: Distribution of Central Government Budget Appropriations and Outlays on R&D by Socio-Economic Objectives*, 2008-2021**

Year	08	09	10	11	12	13	14	15	16	17	18	19	20	21
General Advancement of Knowledge: R&D Financed from General University Funds (GUF)	49.4	47.0	49.4	53.2	56.4	47.5	54.6	53.2	51.3	48.2	45.7	43.6	48.8	44.6
Defense	17.2	22.8	20.0	18.0	14.1	25.6	11.4	10.7	13.1	17.3	20.0	18.7	13.4	28.4
Industrial Production and Technology	7.9	10.2	9.4	7.9	9.0	12.4	14.7	14.1	9.9	9.4	8.9	10.6	10.2	7.9
Transport, Telecommunication and Other Infrastructures	1.4	0.8	0.5	0.4	0.4	0.7	0.4	2.6	6.4	4.4	4.5	5.1	6.7	3.5
Education	2.1	1.4	1.6	1.2	1.9	0.9	2.4	3.3	6.4	5.3	4.0	4.4	5.9	4.1
General Advancement of Knowledge: R&D Financed from Other Sources than GUF	8.0	6.5	6.3	7.7	7.9	6.6	9.3	2.6	2.8	4.4	6.3	7.1	5.7	7.4
Agriculture	2.8	3.6	2.7	3.0	2.5	1.9	1.9	3.2	2.6	2.5	2.3	1.9	2.3	0.5
Health	3.1	2.1	2.7	1.3	1.1	0.2	0.3	2.2	1.9	2.6	1.7	1.8	1.8	1.5
Exploration and Exploitation of the Earth	3.3	1.4	2.6	2.4	2.6	1.8	2.3	2.7	1.8	2.3	2.3	2.3	1.4	0.1
Energy	1.8	1.5	1.9	1.7	1.5	1.0	0.6	2.2	1.7	1.6	1.4	1.5	1.3	0.9
Exploration and Exploitation of Space	0.6	0.7	1.1	0.7	0.3	0.1	0.2	0.3	0.3	0.3	1.7	1.9	1.3	0.6
Environment	1.5	1.2	1.2	1.7	1.2	0.8	0.9	1.9	1.3	1.0	0.9	0.8	0.8	0.3
Political and Social Systems, Structures and Processes	0.6	0.7	0.5	0.9	1.0	0.4	0.4	1.0	0.5	0.5	0.4	0.4	0.4	0.2
Culture, Recreation, Religion and Mass media	0.0	0.1	0.0	0.0	0.0	0.0	0.7	0.1	0.1	0.0	0.0	0.0	0.0	0.0

Source: TURKSTAT, Central Government Budget Appropriations and Outlays on R&D, 2021. *The Nomenclature for the Analysis and Comparison of Scientific Programs and Budgets. **Calculations are based on initial appropriations for 2021 and actual outlays for 2020. **Note:** The list is sorted from the largest to the smallest share with respect to 2020.

Table 1 is sorted from the largest to the smallest share with respect to values of socio-economic objectives in 2020. There was covid-19 in 2020 and this year shows the importance of socio-economic objectives during the pandemic. However, the first

three socio-economic objectives are the same every time even if it is not sorted. Almost half of the budget or more than half was devoted to general advancement of knowledge (R&D financed from general university funds—GUF). The second highest part of the budget was devoted to defense (from 11% to 28%). The third highest part of the budget was devoted to industrial production and technology (from 7.9% to 14.7%).

According to the sorted table, the fourth highest part of the budget was devoted to transport, telecommunication, and other infrastructures. However, without sorting the table, the fourth highest part was generally devoted to general advancement of knowledge (R&D financed from other sources than GUF).

The rest of the budget was devoted to other socio-economic objectives such as: education; agriculture; health; exploration and exploitation of the earth; energy; exploration and exploitation of the space; environment; and political and social systems; structures; and processes; culture; recreation; religion and mass media.

This chapter explains the importance of S&T, R&D, and education, the connection among them, policies on them that are in the 5YDPs, and R&D statistics in Türkiye are interpreted. The importance of S&T, R&D, and education, and the connection among them are emphasized. Development plans are explained by focusing on R&D, S&T, innovation, and education to support the process of understanding the changes in the policies in Türkiye. In addition, R&D statistics in Türkiye is presented in detail and visualized by using TURKSTAT's public data on its website. The real growth rates of some statistics such as R&D statistics are calculated and visualized. For instance, in 2021 in Türkiye, the real R&D expenditure is approximately ₺28 billion that is approximately 1.4% of GDP, and the number of R&D personnel is approximately 358.000 in headcount. Moreover, there is an increase in R&D expenditure and increase in the number of R&D personnel. In this sense, more R&D expenditure and R&D personnel must increase the likelihood of occurrence of product and process innovation in Turkish manufacturing industry. These kinds of statistics are also detailed by sectors such as FNFC, GG, and HE. These statistics help to understand Turkish R&D structure and characteristics.

In this dissertation, Turkish manufacturing firms that engaged in R&D are analyzed for the years between 2009-2016 to reveal the relationships between innovation (product and process) and its determinants (such as R&D expenditure, R&D intensity, *R&D personnel intensity*, *turnover*, market structure, number of high educated R&D personnel, *industrial production index by manufacturing industry sectors*) from the five perspectives that are explained in the introduction of the dissertation. In the next chapter, methodology and data about this analysis are explained in detail.



CHAPTER THREE

METHODOLOGY AND DATA

In chapter I, the theoretical framework of the dissertation is provided by regarding R&D and innovation. In Chapter II, the importance of S&T, R&D activities, and education is emphasized, and R&D statistics in detail in Türkiye is explained by supporting with many figures.

As it is explained before, this dissertation aims to analyze Turkish manufacturing firms that engaged in R&D between 2009 and 2016 by investigating relationships between product and process innovations and their determinants from the five different perspectives that are explained in the introduction of the dissertation.

In this chapter, research methodology and research design are explained in detail such as research model and hypotheses, micro data sets, panel data generation, and classification of Turkish manufacturing industry. In the analysis of Turkish manufacturing industry, the probit model with population-averaged estimator, instead of random effect estimator, is used to analyze the panel data with binary dependent variables such as product (PD) and process (PC) innovation (if a firm introduces innovation—1, otherwise—0) with robust standard error method, within-unit exchangeable correlation structure (equal-correlation model), and confidence level 90 percent. To do this, panel data is generated from some micro data sets in A Group Data in TURKSTAT such as Annual Industry and Service Statistics (AISS), Research and Development Activities Surveys in Business Enterprise Sector (RDAS), Annual Industrial Products (PRODCOM) Statistics, and Innovation Survey (IS).

3.1. Research Methodology

This dissertation aims to analyze the effect of R&D expenditure on technological change (product and process innovation) in Turkish Manufacturing Industry for the period between 2009 and 2016 by the classifications of NACE Rev. 2 (2-digits), TI, EII, and FS. In other words, in this dissertation, Turkish manufacturing

firms that engaged in R&D are analyzed for the years between 2009 and 2016 to reveal the relationships between innovation (product and process) and its determinants (such as *R&D expenditure types*, *R&D intensity types*, *R&D personnel intensity*, *turnover*, *market structure*, *number of high educated R&D personnel*, *industrial production index by manufacturing industry sectors*) from the five perspectives that are explained in the introduction of the dissertation.

The research on Turkish manufacturing industry in this dissertation is a longitudinal research, particularly a panel data study that means data collected repeatedly over time. This research is also quantitative research, particularly secondary data analysis.

Firm-level micro data sets are used such as AISS, RDAS, PRODCOM, and IS. These micro data sets are gathered via administrative records and questionnaire by TURKSTAT. To conduct the analysis, panel data is generated by merging four different firm-level micro data sets. It is important to state that only firm ID no in PRODCOM data set is used for a few years to support data merging process, in other words, features/variables in PRODCOM data set are not considered and used in the analysis.

Generating panel data is not enough for an analysis. After generating panel data by merging/appendix processes, the data must be cleaned. The data cleaning process is a important and critical process for an analysis because it can affect the results of the analysis. That is why panel data is cleaned in this analysis. Then, proxy variables and other variables are generated such as R&D expenditures and R&D intensities.

To do all these things, software programs are used for the analysis such as Stata (mainly), Microsoft Excel (to edit data rapidly), and SAS (faster working on huge amounts of raw data to filter).

3.1.1. Research Model

The determination of the research model is significant for the analysis process. Song and Oh (2015) suggested to study on exploring determinants of innovation by

using different analytical methods such as panel regression. In this dissertation, panel data is generated to analyze Turkish manufacturing industry.

Because panel data is generated, panel data models are discussed here. Especially, panel data models with limited dependent variables such as logit and probit models are explained because the likelihood of occurrence of product and process innovation is aimed to analyze in the analysis of Turkish manufacturing industry from five different perspectives that explained in the introduction of the dissertation.

In the analysis of Turkish manufacturing industry, the probit model with population-averaged estimator, instead of random effect estimator, is used to analyze the panel data with binary dependent variables such as product (PD) and process (PC) innovation (if a firm introduces innovation—1, otherwise—0) with robust standard error method, within-unit exchangeable correlation structure (equal-correlation model), and confidence level 90 percent. The population-averaged probit model provides marginal expectations of the outcome, in other words the average response effect across all clusters (the overall effect, the average effect over the entire sample) (McGahan, 2017).

3.1.1.1. Panel Data Models

Panel data (or longitudinal data) are comprised of both cross-sectional and time series data and same individuals / firms can be tracked over time (Gujarati, 2015; Wooldridge, 2020). Panel data models are separated into five types, and they are classified by their parameters that are constant or changeable according to units and time such as (Yerdelen Tatoğlu, 2018b):

- The Classical Model: Constant coefficient and slope parameters are constant according to units and time. In other words, all observations are homogenous. The estimation method of least squares is suitable in this model.

$$Y_{it} = \beta_0 + \sum_{k=1}^K \beta_k X_{kit} + \mu_{it} \quad i = 1, \dots, N; t = 1, \dots, T \quad (27)$$

- The Unit Effects Model (One-Way): Constant coefficient can change by units, and slope parameter is constant.

$$Y_{it} = \beta_{0i} + \sum_{k=1}^K \beta_k X_{kit} + \mu_{it} \quad i = 1, \dots, N; t = 1, \dots, T \quad (28)$$

- The Unit and Time Effects Model (Two-Way): Constant parameter is changeable by units and time, and slope parameter is constant.

$$Y_{it} = \beta_{0it} + \sum_{k=1}^K \beta_k X_{kit} + \mu_{it} \quad i = 1, \dots, N; t = 1, \dots, T \quad (29)$$

- All parameters are changeable by units, and they are constant by time.

$$Y_{it} = \beta_{0i} + \sum_{k=1}^K \beta_{ki} X_{kit} + u_{it} \quad i = 1, \dots, N; t = 1, \dots, T \quad (30)$$

- All parameters are changeable by units and time.

$$Y_{it} = \beta_{0it} + \sum_{k=1}^K \beta_{kit} X_{kit} + \mu_{it} \quad i = 1, \dots, N; t = 1, \dots, T \quad (31)$$

Equation (28) and (29) are the most used models in panel data analysis, and these models are the most convenient models to consider differences by units (Z_i , firm's specific characteristics, talent of firm's manager, quality of management in firms) and time (Z_t , strike, petrol embargo, crisis, natural disasters) in the model with the basic assumption that the effects of omitted variables are represented by constant variable and error term (Yerdelen Tatoğlu, 2018b).

Choosing the method of estimation is important. Therefore, some tests, such as F-test, likelihood ratio (LR) test, and Breusch-Pagan Lagrange Multiplier (LM) test, are used to determine the appropriate methodology. These tests help to check the validity of the classical model against the fixed effect and random effect model. However, these tests do not provide any result about the validity of fixed effect model or random effect model after rejecting the null hypotheses but only the validity of the classical model [in other words, random effect model is valid if there is no correlation among unit (or time) effects and independent variables while fixed effect model is valid if there is correlation] (Yerdelen Tatoğlu, 2018b).

The Hausman specification test is necessary to test random effect model against fixed effect (Gujarati, 2015). With the Hausman specification test, the null hypothesis is tested (H_0 : *Difference in coefficients is not systematic.*) [in other words, there is no correlation among unit (or time) effects and independent variables, and random effect model is valid]. However, as emphasized by Yerdelen Tatoğlu (2018b), the validity of the Hausman specification test is based on some random effect

model assumptions such as: strict exogeneity $[E(V_{it}|X_i) = 0]$; no correlation among unit effects and independent variables $[E(Z_i|X_i) = E(Z_i) = 0]$; no multicollinearity $[rank E(X_i' \dots) = K]$; constant unconditional variance $[E(U_{it}^2) = \sigma_u^2]$; and no autocorrelation $[E(U_{it}|U_{is}) = 0]$. If there is problem with one of the assumptions such as constant unconditional variance, homoskedasticity, and autocorrelation, the Hausman specification test result may not be reliable data (Baltagi, 2005; Yerdelen Tatoğlu, 2018b).

3.1.1.2. Panel Data Models with Limited Dependent Variable

Panel data models with limited dependent variable, in other words, non-linear models, are well-used models in micro econometrics (Yerdelen Tatoğlu, 2018a; Stock and Watson, 2020). These models can be separated into breakdowns such as panel data models with qualitative dependent variables, panel data models with discrete dependent variables, and panel data models with censored dependent variables. Because dependent variables in this dissertation is qualitative, binary response models with qualitative dependent variables are summarized here.

In binary response models, specifically in panel data models with qualitative dependent variables, the dependent variable is 1 ($Y_{it} = 1$) if an event occurred in time t for unit i while it is 0 ($Y_{it} = 0$) if an event did not occur. The probability of being 1 ($Y_{it} = 1$) and the probability of being 0 ($Y_{it} = 0$) is shown as (P_{it}) and ($1 - P_{it}$) respectively. Expected value of Y_{it} is explained as:

$$E(Y_{it}) = 1 \cdot P_{it} + 0 \cdot (1 - P_{it}) = P_{it} \quad (32)$$

Moreover, in time t for unit i , the probability of an event with independent variables is as below:

$$P_{it} = Prob(Y_{it} = 1|X_{it}) = E(Y_{it}|X_{it}) = F(\beta'X_{it}) \quad (33)$$

$$1 - P_{it} = Prob(Y_{it} = 0|X_{it}) = E(Y_{it}|X_{it}) = 1 - F(\beta'X_{it}) \quad (34)$$

Linear probability models are not appropriate for binary models in panel data analysis because predicted value of the model ($\beta'X_{it}$) are either 1 or 0. Because this model is not compatible with nonlinear nature (Stock and Watson, 2020). Instead of it, Yerdelen Tatoğlu (2018a) emphasized that panel logit model, panel probit model,

and complementary log-log model that provide predicted values of dependent variable between 0 and 1 (S-shaped curves) are especially used for panel data. Only panel logit and panel probit models are viewed.

The panel logit model, which is shown in Equation 35, uses standard logistic cumulative distribution function and provides odds ratios $\{\ln[P_{it}/(1 - P_{it})]\}$ while the panel probit model, which is shown in Equation 36⁶¹ uses standard normal cumulative distribution function (Baltagi, 2011; Stock and Watson, 2020; Wooldridge, 2020). The probability of the occurrence of an event is assumed to be determined by these functions.

$$E(Y_{it}) = \Lambda(\beta'X_{it}) = \frac{1}{1+e^{-\beta'X_{it}}} = \frac{e^{\beta'X_{it}}}{1+e^{-\beta'X_{it}}} \quad (35)$$

$$E(Y_{it}) = \Phi(\beta'X_{it}) = \int_{-\infty}^{\beta'X_{it}} f(z)dz \quad (36)$$

To find the marginal effect in the probability of being 1 (in other words, the effect of changes in X_{it} on the probability), marginal effect equations of panel logit, which is shown in Equation 37, and panel probit, which is shown in Equation 38, can be written as below:

$$\frac{\partial E(Y_{it})}{\partial (X_{it})} = \frac{\partial (P_{it})}{\partial (X_{it})} = \frac{\partial [\Lambda(\beta'X_{it})]}{\partial (X_{it})} = \frac{\partial [\frac{e^{\beta'X_{it}}}{1+e^{-\beta'X_{it}}}]}{\partial (X_{it})} = \Lambda(\beta'X_{it})[1 - \Lambda(\beta'X_{it})]\beta \quad (37)$$

$$\frac{\partial E(Y_{it})}{\partial (X_{it})} = \frac{\partial (P_{it})}{\partial (X_{it})} = \frac{\partial [\Phi(\beta'X_{it})]}{\partial (X_{it})} = \Phi(\beta'X_{it})\beta \quad (38)$$

In this dissertation, panel logit models can be separated into three groups such as random effects, conditional fixed effects, and population-averaged models while panel probit models can be separated into two groups such as random effects and population-averaged models. Because these two models are producing similar results, only way to determine the model between them is to pick one of them, which is better for statistical software (Gujarati, 2015; Stock and Watson, 2020). In this dissertation, panel probit model is used to analyze the effect of R&D expenditure on the likelihood of occurrence of product and process innovation in Turkish manufacturing industry.

⁶¹ $f(z)$ is a cumulative density function and $z \sim N(0,1)$.

Moreover, there is no conditional fixed effects model for panel probit, and estimation of unconditional fixed effects model are biased (STATA, 2021). Because there are only random effects and population-averaged panel probit model, and because the Hausman specification test is necessary to test random effect model against fixed effect, the Hausman test cannot be applied to the panel probit model.

In this dissertation, the probit model with population-averaged estimator is used to analyze the panel data with binary dependent variables such as product (PD) and process (PC) innovation (if a firm introduces innovation—1, otherwise—0) instead of random effects, with robust standard error method, within-unit exchangeable correlation structure (equal-correlation model)⁶², and confidence level 90 percent.

Sribney (n.d.) explained that population parameters of random effects probit model (b) and population-averaged probit model (b^*) are same if correlation is zero between them and emphasized that population-averaged probit model (in other words, marginal effect model) expresses only marginal distribution. There are slight differences between random effects and population-averaged estimators. The population-averaged probit model provides marginal expectations of the outcome, in other words the average response effect across all clusters (the overall effect, the average effect over the entire sample) (McGahan, 2017). In addition, to estimate the average effects of independent variables on dependent variables, population-averaged model is more appropriate (Szmaragd et al., 2013).

The robust (empirical) standard error method uses the actual variation in the cluster-level statistics. There are many attributes with this method such as: standard errors are based on this robust variance estimator (in other words, the Huber/White/sandwich estimator of variance) and are homoscedastic; there is no need to likelihood ratio tests (LR-test) because of inappropriate; and instead of LR-test, Wald-test is appropriate (Arellano, 2003; Hanley et al., 2003; Wooldridge, 2020; STATA, 2021). According to Mancl and DeRouen (2001), robust variance estimator produces valid standard errors even if correlation structure of the population-averaged

⁶² There is another way to use population-averaged panel data model with exchangeable correlation structure, shortly Generalized Estimating Equation (GEE) model (a marginal model for the mean response). It is asymptotic to the number of clusters (the more clusters better results).

panel data model is not correct structure. To get this conclusion, the observation number must be more than or equal to forty. Even if there is a noncanonical link⁶³, robust variance estimator produces valid standard errors, but the model must truly specify the mean. That is why standard errors are labeled as semirobust.

Correlation structure of the population-averaged panel data model is within-unit exchangeable correlation structure⁶⁴ (in other words, equal-correlation model, $corr[Y_{it}, Y_{it'} | X_{it}] = \alpha$) that explains the pattern of association among firms that are within each cluster. This structure states that there is constant autocorrelation within unit and constant variance (homoscedasticity)⁶⁵. Yerdelen Tatoğlu (2018b) underlined that within-unit heteroscedasticity is not a significant problem for panel data because generally heteroscedasticity does not happen within unit (it happens generally in cross-section data), but there is generally within-unit autocorrelation because of omitted unit effect variable. Additionally, panel data set of the analysis is short panel data set [the number of observations (N) is relatively small compared to the number of time periods (T), $N > T$] so autocorrelation may be a minor concern.

Under these main attributes of model, the analysis of Turkish manufacturing industry firms that conducted research and development (R&D) has been carried out for the period spanning 2009 to 2016. This analysis covers five perspectives that are introduced in the dissertation.

The analysis of Turkish manufacturing industry includes twenty different model because of statistically significant and relatively high correlation among five R&D expenditures and among five R&D intensities, which is shown in Appendix 5. In other words, if only one model is used, multicollinearity problem occurs. Because

⁶³ Hardin and Hilbe (2018) explained that canonical means natural. This term is associated with Generalized Linear Models (GLMs). Canonical link function (derived from the exponential family of distributions), as a location parameter, is directly related to the means of the response variable. However, noncanonical link functions (such as probit, log, clog-log, log-log, log-complement etc.) are associated with binomial family. Noncanonical links provide a standard errors problem.

⁶⁴ $\begin{pmatrix} 1 & a & a \\ a & 1 & a \\ a & a & 1 \end{pmatrix}$, where a is covariance. If it is not zero, there is autocorrelation in a unit. To determine correlation structure, there is no statistical test.

⁶⁵ Generalized Estimating Equation (GEE) approach is proposed by Liang and Zeger (1986) to allow for autocorrelation.

of this reason, twenty models are used in this dissertation after R&D expenditure and R&D intensity are separated into their breakdowns. These models and the hypotheses are matched for analysis, which is shown in Table 2.

Table 2: Matching of Hypotheses and Research Models

H1:	<i>PDRE1</i>	H2:	<i>PDRI1</i>	H3:	<i>PCRE1</i>	H4:	<i>PCRI1</i>
H1a:	<i>PDRE2</i>	H2a:	<i>PDRI2</i>	H3a:	<i>PCRE2</i>	H4a:	<i>PCRI2</i>
H1b:	<i>PDRE3</i>	H2b:	<i>PDRI3</i>	H3b:	<i>PCRE3</i>	H4b:	<i>PCRI3</i>
H1c:	<i>PDRE4</i>	H2c:	<i>PDRI4</i>	H3c:	<i>PCRE4</i>	H4c:	<i>PCRI4</i>
H1d:	<i>PDRE5</i>	H2d:	<i>PDRI5</i>	H3d:	<i>PCRE5</i>	H4d:	<i>PCRI5</i>

Source: Created by Author. PD: Product Innovation; PC: Process Innovation; RE: R&D Expenditure; RI: R&D Intensity.

In this dissertation, general model can be written as below:

$$Prob(Y_{it} = 1|X_{it}) = \phi[\beta_0 + \beta_1(X_1) + \beta_2(X_2) + \beta_3(X_3) + \beta_4(X_4) + \beta_5(X_5) + \beta_6(X_6) + \varepsilon_{it}] \quad (39)$$

where “ Y_{it} ” is stands for product innovation (PD) and process innovation (PC). In other words, PDRE, PCRE, PDRE, and PDRI models, which are shown in Table 3, are represented by “ Y_{it} ”. “ X_1 ” stands for *total R&D expenditure, internal R&D expenditure, external R&D expenditure, external-domestic R&D expenditure, and external-foreign R&D expenditure*. These R&D expenditure variables are inflation-adjusted variables, and their logarithm are taken. “ X_1 ” also stands for *total R&D intensity, internal R&D intensity, external R&D intensity, external-domestic R&D intensity, and external-foreign R&D intensity*. X_2 stands for *R&D personnel intensity*. X_3 stands for *turnover*. Turnover is an inflation-adjusted variable, and its logarithm are taken. X_4 stands for *Herfindahl-Hirschman Index (HHI)*. X_5 stands for *industrial production index by manufacturing industry*. Details about all models is shown in Appendix 7, 8, 9, and 10. Moreover, summary of the research models are shown together with label of variables in Table 3.

Table 3: Summary of Research Models

Product Innovation (PD) Models	Process Innovation (PC) Models	Variable Label	Other variables
PDRE1	PCRE1	Total R&D Exp.	-R&D (Personnel) Intensity
PDRE2	PCRE2	Total Internal R&D Exp.	
PDRE3	PCRE3	Total External R&D Exp.	-Inflation-Adjusted Turnover
PDRE4	PCRE4	Total External-Domestic R&D Exp.	
PDRE5	PCRE5	Total External-Foreign R&D Exp.	-Herfindahl-Hirschman Index
PDRI1	PCRI1	Total R&D Int.	
PDRI2	PCRI2	Total Internal R&D Int.	-Number Of R&D Personnel
PDRI3	PCRI3	Total External R&D Int.	
PDRI4	PCRI4	Total External-Domestic R&D Int.	-Industrial Production Index by Manufacturing Industry
PDRI5	PCRI5	Total External-Foreign R&D Int.	

Source: Created by Author. PD: Product Innovation; PC: Process Innovation; RE: R&D Expenditure; RI: R&D Intensity. Exp.: Expenditure; Int.: Intensity.

Then, it is assumed for all these models (PDRE, PCRE, PDRE, and PDRI models) that the effect of all these independent variables on product or process innovation is positive. This assumption is based on many studies. For instance, Maclaurin (1953) specified that the propensity to innovate is one of the measurable elements of technological progress. This propensity is defined as the share of R&D expenditure and rate of introducing product and process innovations by Dosi (1988) in terms of sectoral differences. Dosi (1988) emphasized that most of studies concerned the relationship between R&D expenditure (resources) and rate of introducing product and process innovations. The likelihood of occurrence of innovation in a sector depends on R&D expenditure, especially *total R&D expenditure* (Barro and Sala-i-Martin, 2004). Audretsch, Menkveld, and Thurik (1996) showed that in Netherlands, there is a positive effect between R&D personnel and the probability that firms

engaging internal and external R&D. Hall, Lotti, and Mairesse (2009) showed that in Italia, R&D intensity have positive effect on the probability of process and product innovation. Clausen, Korneliussen, and Madsen (2013) showed that in Norway, more market and technological resources of a firm increase likelihood of introducing new product innovation. Adeyeye et al. (2016) showed that there is a positive relationship between tangible investments and likelihood of introducing product innovation to the market. Baumann and Kritikos (2016) emphasized that in Germany, R&D and highly skilled employees cause to increase the likelihood of introducing an innovation, and its effect on product innovation is bigger than on process.

3.1.2. Research Hypotheses

Hypothesis is a statement that can be tested scientifically and based on a relationship between variables or based on observed cases, in other words, it is theoretical expectation from coefficients of the model. In this dissertation, hypotheses are mainly based on ‘more R&D expenditure more likelihood of occurrence of product and process innovation’ and ‘more R&D intensity more likelihood of occurrence of product and process innovation’ approach.

The general hypothesis is diversified for each R&D expenditure (RE) and each R&D intensity (RI), and product (PD) and process (PC) innovation. Therefore, because there are breakdowns of R&D expenditure, there are five different R&D expenditure variables and therefore five different R&D intensity variables.

R&D expenditure and intensity variables are adapted to main hypotheses and ten hypotheses are formed. Then, these ten hypotheses are also adapted to product and process innovations. After all, twenty alternative hypotheses are summarized in Table 4, 5, 6, and 7.

Alternative hypotheses for product innovation and R&D expenditure, called PDRE models, are seen in Table 4. In these models, “ Y_{it} ” stands for product innovation and “ X_1 ” stands for R&D expenditure variables such as *total R&D expenditure*, *internal R&D expenditure*, *external R&D expenditure*, *external-domestic R&D expenditure*, and *external-foreign R&D expenditure*.

Table 4: Hypotheses for Product Innovation (PD) and R&D Expenditure (RE)

H1:	Increase in <i>total R&D expenditure</i> increases the likelihood of occurrence of product innovation.
H1a:	Increase in <i>internal R&D expenditure</i> increases the likelihood of occurrence of product innovation.
H1b:	Increase in <i>external R&D expenditure</i> increases the likelihood of occurrence of product innovation.
H1c:	Increase in <i>external-domestic R&D expenditure</i> increases the likelihood of occurrence of product innovation.
H1d:	Increase in <i>external-foreign R&D expenditure</i> increases the likelihood of occurrence of product innovation.

Alternative hypotheses for product innovation and R&D intensity, called PDRI models, are seen in Table 5. In these models, “ Y_{it} ” stands for product innovation and “ X_1 ” stands for R&D intensity variables such as *total R&D intensity*, *internal R&D intensity*, *external R&D intensity*, *external-domestic R&D intensity*, and *external-foreign R&D intensity*.

Table 5: Hypotheses for Product Innovation (PD) and R&D Intensity (RI)

H2:	Increase in <i>total R&D intensity</i> increases the likelihood of occurrence of product innovation.
H2a:	Increase in <i>internal R&D intensity</i> increases the likelihood of occurrence of product innovation.
H2b:	Increase in <i>external R&D intensity</i> increases the likelihood of occurrence of product innovation.
H2c:	Increase in <i>external-domestic R&D intensity</i> increases the likelihood of occurrence of product innovation.
H2d:	Increase in <i>external-foreign R&D intensity</i> increases the likelihood of occurrence of product innovation.

Alternative hypotheses for process innovation and R&D expenditure, called PCRE models, are seen in Table 6. In these models, “ Y_{it} ” stands for process innovation and “ X_1 ” stands for R&D expenditure variables such as *total R&D expenditure*, *internal R&D expenditure*, *external R&D expenditure*, *external-domestic R&D expenditure*, and *external-foreign R&D expenditure*.

Table 6: Hypotheses for Process Innovation (PC) and R&D Expenditure (RE)

H3:	Increase in <i>total R&D expenditure</i> increases the likelihood of occurrence of process innovation.
H3a:	Increase in <i>internal R&D expenditure</i> increases the likelihood of occurrence of process innovation.
H3b:	Increase in <i>external R&D expenditure</i> increases the likelihood of occurrence of process innovation.
H3c:	Increase in <i>external-domestic R&D expenditure</i> increases the likelihood of occurrence of process innovation.
H3d:	Increase in <i>external-foreign R&D expenditure</i> increases the likelihood of occurrence of process innovation.

Alternative hypotheses for process innovation and R&D intensity, called PDRI models, are seen in Table 7. In these models, “ Y_{it} ” stands for process innovation and “ X_1 ” stands for R&D intensity variables such as *total R&D intensity*, *internal R&D intensity*, *external R&D intensity*, *external-domestic R&D intensity*, and *external-foreign R&D intensity*.

Table 7: Hypotheses for Process Innovation (PC) and R&D Intensity (RI)

H4:	Increase in <i>total R&D intensity</i> increases the likelihood of occurrence of process innovation.
H4a:	Increase in <i>internal R&D intensity</i> increases the likelihood of occurrence of process innovation.
H4b:	Increase in <i>external R&D intensity</i> increases the likelihood of occurrence of process innovation.
H4c:	Increase in <i>external-domestic R&D intensity</i> increases the likelihood of occurrence of process innovation.
H4d:	Increase in <i>external-foreign R&D intensity</i> increases the likelihood of occurrence of process innovation.

3.2. Research Design

Micro data sets in A Group Data in TURKSTAT such as Annual Industry and Service Statistics (AISS), Research and Development Activities Surveys in Business Enterprise Sector (RDAS), Annual Industrial Products (PRODCOM) Statistics, and

Innovation Survey (IS). It is necessary that insights of these micro data sets must be viewed to understand what research design clearly is.

Meta data about micro data sets are significant to understand the core of the analysis, in other words, research design. Each micro data sets are explained below in terms of data period, data collection method, coverage etc.

The most important data sets in the analysis are IS, RDAS, and AISS, in other words, the analysis is based mainly on those three data sets. Since, only ‘firm ID No’ in PRODCOM micro data set was used only for few years to ease data merging process, in other words other variables in this data set was not used.

Table 8: Data Period and Data Collection Method of TURKSTAT for Micro Data Sets

Data Level and Period	Micro Data Sets	Data Collection Method
Firm Level Data, Annually	(1) AISS	Revenue Administration and Social Security Institution administrative records.
	(2) PRODCOM	2005-2012 survey form and face-to-face. After 2012, web-based electronic questionnaire.
	(3) RDAS	Directly from enterprises through web-based electronic questionnaire.
Firm Level Data, Every two years for a three-year period	(4) IS	Web-based electronic questionnaire.

Source: TURKSTAT. AISS: Annual Industry and Service Statistics. PRODCOM: Annual Industrial Products. RDAS: Research and Development Activities Surveys in Business Enterprise Sector. IS: Community Innovation Survey.

IS, RDAS, AISS, and PRODCOM micro data sets must be viewed in their meta data files to understand the data sets in detail. According to meta data interpretations, *the data period* of the micro data sets is annually, except IS which is conducted every two years for a three-year period. *The data collection method* of the micro data sets is significant to understand research process. AISS data was collected using Revenue Administration and Social Security Institution administrative records. RDAS data was collected directly from enterprises through web-based electronic questionnaires. IS

data was collected through web-based electronic questionnaires too. PRODCOM data was collected with survey form and face-to-face interview for the period between 2005 and 2012. After 2012, it is collected through web-based electronic questionnaire too. All information about the data period and the data collection method were summarized in Table 8.

Table 9: Data Coverage of TURKSTAT Micro Data Sets

Micro Data Sets	Coverage
(1) AISS	“Geographical coverage: All provincial and district centers and villages within the borders of the Republic of Türkiye are included in the coverage irrespective of population size geographically. In addition to these settlements, gas stations located on intercity roads, organized industrial zones are included in the geographical scope. Sectoral Coverage: “Sectors constitute coverage of Annual Industry and Service Statistics included in Statistical Classification of Economic Activities in the European Community NACE Rev. 2.” (TURKSTAT, 2020c, p. 6)
(2) PRODCOM	“Enterprises whose primary or secondary activity is in either Mining & Quarrying (B) or Manufacturing Industry (C) section of Industrial Classification of Economic Activities (NACE Rev. 2) and having 20 or more persons employed are covered.” (TURKSTAT, 2020b, p. 6)
(3) RDAS	“Financial and non-financial corporations R&D research includes all enterprises that operate in the industry and service sectors known or predicted to have R&D. • Enterprises known to carry out R&D activities (based on previous research results), • Enterprises operating in Technology Development Zones, • Enterprises supported by the public institutions for R&D activities, Enterprises benefiting from indirect R&D supports under Law No. 5746, • Top 500 enterprises ranked separately in industry and service sector by <i>turnover</i> and value-added.” (TURKSTAT, 2021, p. 14)
(4) IS	“Statistical Classification of Economic Activities in the European (NACE) Rev 2. is based on for the distribution and main activities ... were taken into account” such as “... Manufacturing (NACE-C: 10-33) ...”, and “sectoral coverage is the enterprises with ten or more employees.” (TURKSTAT, 2020a, p. 8)

Source: TURKSTAT. AISS: Annual Industry and Service Statistics. PRODCOM: Annual Industrial Products. RDAS: Research and Development Activities Surveys in Business Enterprise Sector. IS: Community Innovation Survey.

Coverage of micro data sets are necessary to understand which firm is included in the research. All information about the data coverage was summarized in Table 9.

According to meta data interpretations, IS micro data set covers Turkish manufacturing firms that employed 10 or more persons. AISS micro data set can be considered in terms of geographical coverage that covers within the borders of the Republic of Türkiye and sectoral coverage that is based on NACE Rev. 2 classification. RDAS micro data set covers firms that are engaged in R&D activities, operate in TDZ (Technology Development Zone), are supported by public institutions and indirect R&D supports. PRODCOM micro data set focuses on primary or secondary activity of the firms that employed 20 or more persons.

It is important to emphasize here that Turkish manufacturing analysis in this dissertation covers the years between 2009 and 2016. Because the structure of IS questionnaire was changed in 2018.

Turkish manufacturing analysis in this dissertation covers firms that engaged in R&D activities and employed more than 20 or more persons, in the period between 2009 and 2016 by investigating relationships between product and process innovations and their determinants from the five different perspectives that are explained in the introduction of the dissertation.

3.2.1. About Firm-Level Micro Data Sets

All data (variables or features) in four microdata sets are not used for the analysis. For instance, it is important to underline again that firms' ID No is taken from PRODCOM micro data set only for a few years to support data merging process, in other words, there is not any variable/feature except firms' ID No in the analysis. However, there are many variables/features from IS, AISS, and RDAS micro data sets such as product and process innovation, *turnover*, number of employees, R&D expenditure, and number of researchers. Definitions of features/variables and concepts used in the analysis can be found below.

3.2.1.1. Innovation Survey (IS) Micro Data Set

Innovation survey provides dependent variables for analysis such as product and process innovation. To understand better what product and process innovation are, definitions in the IS questionnaire are provided also here.

Product Innovation is defined in the IS as below, and the question for product innovation in the IS can be seen in Table 10.

“A product innovation is the market introduction of a new or significantly improved good or service with respect to its capabilities, user friendliness, components, or sub-systems.

-Product innovations (new or improved) must be new to your enterprise, but they do not need to be new to your market.

-Product innovations could have been originally developed by your enterprise or by other enterprises or organisations.

A good is usually a tangible object such as a smartphone, furniture, or packaged software, but downloadable software, music and film are also goods. A service is usually intangible, such as retailing, insurance, educational courses, air travel, consulting, etc.”

(TURKSTAT, 2012, p. 3)

Table 10: Question for Product Innovation

During the three years 2012 to 2014, did your enterprise introduce:	Yes (1)	No (0)
Goods innovations: New or significantly improved goods (exclude the simple resale of new goods and changes of a solely aesthetic nature)		
Service innovations: New or significantly improved services		

Source: TURKSTAT, 2012, p. 3.

Table 11: Question of Process Innovation

During the three years 2012 to 2014, did your enterprise introduce:	Yes (1)	No (0)
New or significantly improved methods of manufacturing for producing goods or services		
New or significantly improved logistics, delivery or distribution methods for your inputs, goods or services		
New or significantly improved supporting activities for your processes, such as maintenance systems or operations for purchasing, accounting, or computing		

Source: TURKSTAT, 2012, p. 5.

Process Innovation is defined in the IS as above, and the question for process innovation in the IS can be seen in Table 11.

“A process innovation is the implementation of a new or significantly improved production process, distribution method, or supporting activity.

-Process innovations must be new to your enterprise, but they do not need to be new to your market.

- The innovation could have been originally developed by your enterprise or by other enterprises or organisations.
- Exclude purely organisational innovations.”

(TURKSTAT, 2012, p. 5)

3.2.1.2. Annual Industry and Service Statistics (AISS) Micro Data Set

Annual Industry and Service Statistics survey provide features/variables such as *turnover* (sales) and number of employees. These are important to calculate independent proxy variables such as R&D intensity (expenditure related) and R&D intensity (personnel number related). Both R&D intensities are different in terms of representation. R&D intensity (expenditure related) is an indicator of R&D investment while R&D intensity (personnel number related) is an indicator of know-how.

To understand better what *turnover* (sales) and number of employees are, some definitions in the AISS micro data set are also provided here such as NACE Rev. 2, *turnover* (sales), and number of employees.

NACE Rev. 2 is defined in the AISS micro data set as below:

“Main Activity: If the enterprise conducts more than one activity, the main activity is the one that generates the highest portion of the gross sales revenues. If more than one activity generates the same portion of the gross sales revenues, the main activity is the one in which more people are employed.”

(TURKSTAT, 2020c, p. 4)

Turnover (Sales) is defined in the AISS micro data set as “... *the totals invoiced by the observation unit during the reference period, and this corresponds to market sales of goods or services supplied to third parties*” (TURKSTAT, 2020c, p. 8).

Number of Employees is defined in the AISS micro data set as “*those persons who work for an employer and who have a contract of employment and receive compensation in the form of wages, salaries, fees, gratuities, piecework pay or remuneration in kind*” (TURKSTAT, 2020c, p. 8).

3.2.1.3. Research and Development Activities Survey for Business Enterprises (RDAS) Micro Data Set

Research and Development Activities survey provide features/variables such as R&D personnel number by occupation, their level of education by occupation, and

R&D expenditure types [total, intramural (internal), extramural (external), external-domestic, external-foreign].

These are important to calculate independent variables such as inflation-adjusted R&D expenditure, R&D intensity (expenditure related and an indicator of R&D investment), R&D intensity (personnel number related and an indicator of know-how). To understand better what occupation types and R&D expenditure types are, definitions of these concepts in the survey are provided also here such as researchers, technicians/equivalent staff, and other supporting staff, intramural expenditure (internal), extramural expenditure (external).

Researchers are defined as “... professionals engaged in the conception or creation of new knowledge, products, processes, methods and systems and also in the management of the projects concerned” (TURKSTAT, 2015, p. 3).

Technicians and Equivalent Staff are defined as below:

“... persons whose main tasks require technical knowledge and experience in one or more fields of engineering, physical and life sciences or social sciences and humanities. They participate in R&D by performing scientific and technical tasks involving the application of concepts and operational methods, normally under the supervision of researchers. Equivalent staff performs the corresponding R&D tasks under the supervision of researchers in the social sciences and humanities. Their tasks include:

- Carrying out bibliographic searches and selecting relevant material from archives and libraries.*
- Preparing computer programmes,*
- Carrying out experiments, tests and analyses,*
- Preparing materials and equipment for experiments, tests and analyses,*
- Recording measurements, making calculations and preparing charts and graphs,*
- Carrying out statistical surveys and interviews.”*

(TURKSTAT, 2015, p. 3)

Other Supporting Staff is defined as “... skilled and unskilled craftsmen, secretarial and clerical staff participating in R&D projects or directly associated with such projects” (TURKSTAT, 2015, p. 3).

Researchers and other supporting staff are necessary human capital. Researchers are important for a country and an industry to create new knowledge and to innovate and main actor in R&D activities. Additionally, other supporting staff must support them in the R&D activity process.

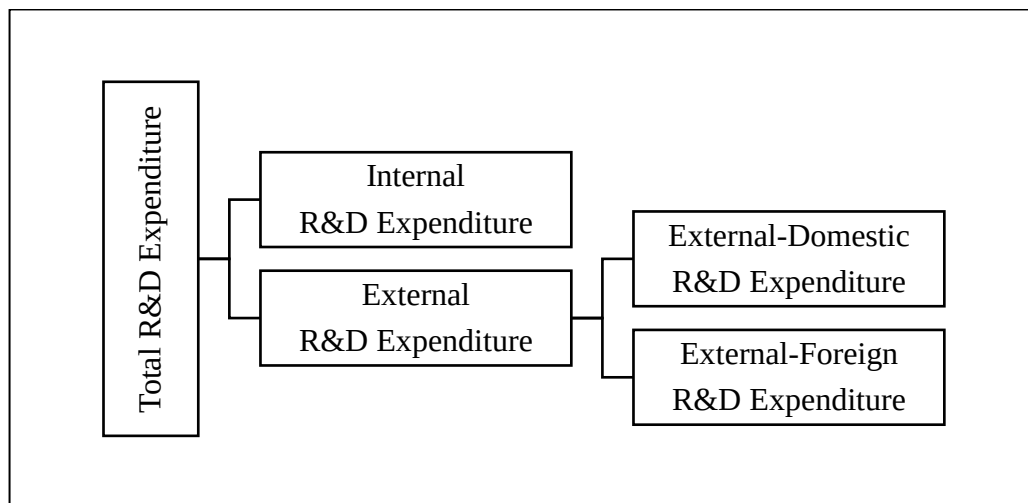
Intramural Expenditures (internal R&D expenditure) are defined in RDAS micro data set as “... all expenditures for R&D performed within a statistical unit or sector of the economy during a specific period, whatever the source of funds” (TURKSTAT, 2015, p. 3).

Table 12: Calculation of Internal R&D expenditure

<i>Internal R&D expenditure</i> = Current Costs + Investment Expenditures + Capitalized Computer Software
Current Costs = R&D Personnel Cost + Other Current Cost of R&D Other Current Cost = Extramural (external) R&D Personnel Expenditures + Purchase of Services + Purchase of Materials + Other
Investment Expenditures = R&D Machinery Equipment + Fixed Facility R&D Machinery Equipment = Information and Communications Equipment + Transportation Equipment + Other Machinery and Equipment Fixed Facility = Land + Buildings
Capitalized Computer Software

Source: Summarized from the surveys by Author.

Extramural Expenditures (external R&D expenditure) are R&D expenditure for R&D purchase or unrequited transfer, and it is defined in RDAS micro data set as “all expenditures for R&D activities that carried out by the institutions/organizations in the country and/or on abroad. It comprises R&D activities made by universities and higher education institutes in return for a grant” (TURKSTAT, 2015, p. 4).



Source: Author's own configuration.

Figure 71: R&D Expenditure by Type

In the RDAS micro data set, *total R&D expenditure* (internal + external) is separated into subgroups such as internal, external, external-domestic, and external foreign, which is shown in Figure 71.

3.2.2. Panel Data Generating Process

Panel data has been used increasingly since the 1990s. It includes observations of a unit (individual, firm, etc.) across multiple periods, and comprises N number of units and T number of observation per unit. It has many advantages such as analysis of changes in units (individual, firm, etc.) over time, controlling for unobserved heterogeneity, reduction of omitted variable bias (endogeneity problem), analysis of more observations that lead to decrease multicollinearity problem, and so on. These advantages makes panel data more worthy. However, there are disadvantages such as data collection problems, short time series problem, and so on.

A panel data is generated by using all firm-level micro data sets to analyze the effect of R&D expenditure on technological change (product and process innovation) in Turkish manufacturing industry for the period between 2009 and 2016 by the classifications of NACE Rev. 2 (2-digits), TI, EII, and FS. To generate panel data, documents must be appended (firstly) and merged, but the order of processes such as merging and appending is not important, in other words both ways are the same. However, panel data is not generated in an instant, in other words it takes a long time because of incompatible document types, data recording, and data types. These small problems must be solved during *the data generating process*. The problems can be explained shortly such as:

- *Differences in Document Types*: Firm-level micro data sets include SAS documents for AISS (as a .csv format), excel documents for PRODCOM and RDAS yearly. IS data is stored as excel documents for every survey period.
- *Data Recording*: Header of the columns is not same for every year. For example, “Y” and “YEAR” are the name of the column for year in two different files. Even if letters are different in terms of capitalization of letters such as

“year” and “YEAR” you must solve this problem to avoid appending and merging errors.

- *Data Types*: Data types are not the same in two different files. For example, data type is string in a file and integer in another. It must be the same to have a healthy appending and merging process.

These kinds of problems about data are a huge impediment to the data generating process. Format of files, header of the columns, and data types must be equalized.

In this dissertation, after altering incompatible points, an unbalanced panel data is generated by appending and merging firm-level micro data sets with respect to firms' ID (Key ID) for the period between 2009 and 2016.

Having this unbalanced panel data does not mean everything is completed. Results and analysis are only as good as panel data set used in research. That is why *the data cleaning process* is significant. In this stage, panel data set is controlled to fix/remove incorrect data, corrupted data, incorrectly formatted data, duplicated or incomplete data. Many steps are applied on the data such as:

- Duplicated data is removed.
- Firms that have zero *turnover* are dropped.
- Firms with less than 20 employees (and with no employees) are dropped.
- To avoid data elimination, empty cells in the panel data set are also considered and filled with zero (0) for some variables such as R&D expenditure and number of highly educated personnel. It is assumed that there is no R&D expenditure, and no highly educated personnel, respectively.

After all these kinds of processes, finally, the basis of the panel data is generated as unbalanced structure. In the next phase, determination and transformation of independent variables, and classification of Turkish manufacturing industry are explained.

3.2.3. Data

After the unbalanced panel data generation phase, independent variables are processed mathematically. For example: price effects are removed on nominal R&D expenditure variables and nominal *turnover*, and logarithmic transformation is applied⁶⁶; some proportions (R&D intensity) are calculated as a proxy variable; Herfindahl-Hirschman Index (*HHI*) is calculated; the *number of highly educated R&D personnel* (graduate level— doctoral and master degree) is calculated; and the industrial production index by the manufacturing industry is used as average of the year for each sector. All these variables are explained here in detail.

Inflation-Adjusted R&D Expenditure is calculated from R&D expenditure variables that are nominal in RDAS micro data set. It is important to state that removing price effects on these nominal values to acquire real R&D expenditure is necessary for better analysis results.

To calculate real R&D expenditure, nominal R&D expenditure is divided by price index (GDP deflator from World Bank for Türkiye) and is multiplied by 100 (2009=100). This process is implemented for all types of R&D expenditure. GDP deflator is defined as “... *the ratio of GDP in current local currency to GDP in constant local currency*” (World Bank, 2022). It is described in detail as:

“This series has been linked to produce a consistent time series to counteract breaks in series over time due to changes in base years, source data and methodologies. Thus, it may not be comparable with other national accounts series in the database for historical years. The base year varies by country.”

(World Bank, 2022)

Because there are five nominal R&D expenditure data (total, internal, external, external-domestic, and external-foreign), price effects are removed on each of them, and natural logarithm of each of them is calculated after zero cells were changed as 1, which is explained clearly in footnote 66.

⁶⁶ As mentioned previously, during the data cleaning process, empty cells are filled with zero in terms of R&D expenditure variables. Because $\log(0)$ is undefined, data is eliminated during the analysis automatically. To solve this problem, these zero cells are changed as 1. Therefore, log transformation is applied for example $\log(1)$ is equal to zero.

Inflation-Adjusted Turnover (Sales) is calculated from *turnover* variable by implementing the same process as mentioned above in terms of calculation real *turnover*. Nominal *turnover* is divided by price index (GDP deflator from World Bank for Türkiye) and is multiplied by 100. Price effects are removed on *turnover*. Last, logarithmic transformation is applied.

R&D Intensity is calculated from two different perspectives. One of them is related to expenditure (R&D expenditure over *turnover*— an indicator of R&D investment), which is used in some studies of Hamberg (1964) and Subrahmanian (1971). The other is related to personnel number (R&D personnel number over total personnel number— an indicator of know-how). Although both are called R&D intensity, in this dissertation, the first one is called R&D intensity, and the other one is called *R&D personnel intensity*.

Because there are five R&D expenditure data (total, internal, external, external-domestic, and external-foreign), expenditure related R&D intensity is calculated for each of them by using the ratio, which is shown in Equation 40. Personnel related R&D intensity is calculated for each of them by using the ratio, which is shown in Equation 41.

$$\text{Expenditure related R\&D Intensity} = \frac{\text{R\&D Expenditure types}}{\text{Turnover}} \quad (40)$$

$$\text{Expenditure related R\&D Intensity} = \frac{\text{Total R\&D Personnel Number}}{\text{Total Personnel Number}} \quad (41)$$

The *Herfindahl-Hirschman Index (HHI)* is considered in this analysis as a proxy for the market concentration. To check this intensity of competition, there are few proxies such as concentration ratio (CR4, CR8, etc.) and Herfindahl-Hirschman Index. Because the market share of all firms is considered during the calculation, the *HHI* is more comprehensive than the CR. *HHI* is calculated by using Equation 42.

$$HHI = \sum_{i=1}^n s_{ij}^2 \quad (42)$$

where “s” stands for market share of n^{th} firm in an industry, where “i” stands for firm and “j” stands for manufacturing industry.

High Educated R&D Personnel Number is the total number of R&D personnel with doctoral and master's degrees, in other words graduate degrees.

Industrial production index by manufacturing industry is used as a variable in the analysis. The annual average of industrial production index is calculated for the period between 2009 and 2016 and for each manufacturing industry separately by using TURKSTAT's unadjusted industrial production index data (2015=100). After that, the index is changed to 2009=100 to equalize variables.

After those time-consuming calculation and transformation processes, panel data is better with new variables and proxies like mentioned above. Missing control is also done and there are no missing variables in this unbalanced panel data.

3.2.3.1. Multicollinearity Check and Independent Variables

Independent variables are usually checked for whether there is multicollinearity between or among independent variables or not, which is one of the main assumptions in econometrics and a problem related with sample and which creates biasedness. As mentioned by Yerdelen Tatoğlu (2020), there are many reasons for multicollinearity such as independent variables that have same trends, insufficient data set and distributed lag model. She emphasized the results of multicollinearity such as: if there is complete correlation between independent variables ($r=1$), parameters cannot be estimated; if there is no correlation between independent variables ($r=0$), estimations cannot be affected; if level of multicollinearity is less (close to 0), the model may not be affected adversely.

According to correlation matrix among variables, which is shown in Appendix 5, to check multicollinearity, there are some significant and insignificant, and weak and moderate correlations among variables.

Correlations between dependent and independent variables are generally significant and weak, as they are shown in Appendix 5. However, some correlations are insignificant such as: between product innovation and some independent variables (*internal R&D intensity* and *external-domestic R&D intensity*); and between process innovation and some independent variables (*total R&D intensity*, *internal R&D*

intensity, and *external-domestic R&D intensity*). Some other correlations are significant and relatively moderate and less than moderate such as: between product innovation and some variables (*total R&D expenditure*⁶⁷, *turnover*⁶⁸); and between process innovation and some variables (*total R&D expenditure*⁶⁹, *turnover*⁷⁰).

Correlations between independent variables are also generally found significant and weak, as they are shown in Appendix 5. However, some correlations are insignificant such as: between *R&D personnel intensity* and *external-foreign R&D expenditure*; between *turnover* and *external-foreign R&D intensity*; between *HHI* and all R&D intensity variables; between number of high educated R&D personnel and some variables (*external R&D intensity* and *external-domestic R&D intensity*); and between *industrial production index by manufacturing industry* and some variables (*external R&D expenditure*, *external-domestic R&D expenditure*, and all R&D intensities, *HHI*, number of high educated R&D personnel). Some other correlations are significant and relatively moderate and less than moderate such as: between *R&D personnel intensity* and some variables (*total R&D expenditure*⁷¹, *internal R&D expenditure*⁷², R&D intensities⁷³ except external-foreign); between *turnover* and some variables (all R&D expenditures⁷⁴, R&D intensities⁷⁵ except external-foreign, *R&D personnel intensity*⁷⁶); between *HHI* and *R&D personnel intensity*⁷⁷; between number of high educated R&D personnel and some variables (all R&D expenditures⁷⁸, *R&D*

⁶⁷ Positive and 21%, approximately.

⁶⁸ Positive and 11%, approximately.

⁶⁹ Positive and 21%, approximately.

⁷⁰ Positive and 18%, approximately.

⁷¹ Positive and 20% approximately.

⁷² Positive and 20% approximately.

⁷³ Positive and 50% (total R&D intensity, internal R&D intensity), positive and 23% (external R&D intensity, external-domestic R&D intensity), approximately.

⁷⁴ Positive and 56% (total R&D expenditure, internal R&D expenditure), positive and 18% (external R&D expenditure, external-foreign R&D expenditure), positive and 17% (external-domestic R&D expenditure), approximately.

⁷⁵ Negative and 14% (total R&D intensity, internal R&D intensity), negative and 9% (external R&D intensity, external-domestic R&D intensity), approximately.

⁷⁶ Negative and 33% (R&D personnel intensity), approximately.

⁷⁷ Positive and 12%, approximately.

⁷⁸ Positive and 34% (total R&D expenditure, internal R&D expenditure), positive and 10% (external R&D expenditure), positive and 11% (external-domestic R&D expenditure), and positive and 12% (external-foreign R&D expenditure), approximately.

*personnel intensity*⁷⁹, *turnover*⁸⁰); and between *industrial production index by manufacturing industry* and some variables (total and *internal R&D expenditure*⁸¹, *R&D personnel intensity*⁸², *turnover*⁸³).

In this dissertation, panel data is generated. R&D expenditures and *turnover* are deflated from price effects and their logarithms are taken. Moreover, Variance Inflation Factor (VIF) criteria is checked⁸⁴. Therefore, independent variables are determined, and their names and labels are shown in Appendix 4. In addition, descriptive statistics of the data are shown in Appendix 6.

3.2.4. Classification of Turkish Manufacturing Industry

Turkish manufacturing industry is analyzed in this dissertation by the classifications of NACE Rev. 2 (2-digits), TI, EII, and FS.

3.2.4.1. Classification of Economic Activities (NACE Rev. 2)

Song and Oh (2015) suggested to study differences by industry in terms of likelihood of occurrence of innovation. So, these differences are aimed to research in Turkish manufacturing industry. Then, classification of Turkish manufacturing industry by NACE Rev. 2 section C (all manufacturing industry) and 2-digit is used.

NACE is a statistical classification system for economic activities in the European Community such as manufacturing and service sectors. It is revised mainly two times: the first revision is NACE Rev. 1 (additionally, NACE Rev 1.1) between 2000 and 2007; and the second revision is NACE Rev. 2 that was standard

⁷⁹ Positive and 18%, approximately.

⁸⁰ Positive and 20%, approximately.

⁸¹ Positive and 8%, approximately.

⁸² Positive and 12%, approximately.

⁸³ Negative and 14%, approximately.

⁸⁴Yerdelen Tatoğlu (2020) emphasized that VIF criteria must be checked to be sure about multicollinearity. Because of this, VIF criteria is used to check multicollinearity. Model is estimated with method of least squares and then calculated VIF criteria. According to the results, all VIF criteria are less than 5 (close to 1) so mean VIF is also less than 5. In other words, multicollinearity problem is solved by removing problematic independent variables (Square of Inflation-Adjusted Turnover, Industrial Production Index-all, and Real Sector Confidence Index). It is important to note that this VIF Criteria analysis is completed in Data Research Center of TURKSTAT in İstanbul. The analysis was completed in November 2022, but it is not shared by TURKSTAT to me. Because of this, VIF Criteria Analysis table could not be shared in the Appendixes.

classification in 2009 and more comprehensive and beneficial for statistical analysis and economic governance.

Turkish manufacturing industry is classified by NACE Rev. 2 and TURKSTAT provides data sets based on it, which is shown in Appendix 1. NACE Rev. 2 codes are significant to follow sectors and their differences. In this dissertation, NACE Rev. 2 at 2-digit level is used for the analysis. The other levels such as 3-digit, 4-digit, and 6-digit are not used because they result in a loss of data, in other words subsectors has low number of observations about firms that engaged in R&D in Türkiye.

3.2.4.2. Technology Intensity (TI) Classification

Technology intensity classification is used to analyze manufacturing industry in many studies such as Lee (2004) and Bhattacharya and Bloch (2004). Lee (2004) showed that, in Malaysian manufacturing industry, firms in high-tech industries are more innovative than firms in low tech industries, but there is a contradiction. Bhattacharya and Bloch (2004) showed that, in Australian manufacturing industry, there are positive relationship between innovation and R&D intensity (R&D expenditure/sales) but there are differences between high tech and low-tech industries. So, in this dissertation, technology intensity classification is used to reveal differences by this classification in terms of likelihood of occurrence of innovation.

EUROSTAT provides technology intensity classification that is based on NACE Rev. 2 at 2-digit level (EUROSTAT, 2022). Classification table is shown in Appendix 2. This classification separates manufacturing industry into four types of intensities such as High Technology (HT), Medium-High Technology (MHT), Medium-Low Technology (MLT), and Low Technology (LT).

In this dissertation, NACE Rev. 2 at 2-digit level is used for the analysis. 3-digit level, 4-digit level, and 6-digit level are not used because they result in a loss of data., in other words subsectors has low number of observations about firms that engaged in R&D in Türkiye.

3.2.4.3. Education Intensity (EII) Classification

The manufacturing industry is classified by education intensity based on NACE Rev. 2 at 2-digit level by using number of R&D personnel by their education level and year of schooling as a weighting factor.

Education intensity index (EII) is used to classify Turkish manufacturing industry based on NACE Rev. 2 at 2-digit level. The classification of the industry involves four groups such as High Education Intensity (HEI), Medium-High Education Intensity (MHEI), Medium-Low Education Intensity (MLEI), and Low Education Intensity (LEI).

EII is calculated for each year on average (2009-2016) by using the number of R&D personnel by their education level in each industry under the weighted mean approach, which is shown in Equation 43.

$$\text{Weighted Mean} = \frac{\sum_{i=1}^n x_{tji} w_i}{\sum w_i} = \frac{(x_{tj1} w_1 + x_{tj2} w_2 + \dots + x_{tjn} w_n)}{w_1 + w_2 + \dots + w_n} \quad (43)$$

x stands for the number of R&D personnel, w stands for year of schooling as a weighting factor, t stands for year (2009-2016), j stands for manufacturing sector (between 10 and 33 by NACE Rev. 2 at 2-digit level), i stands for education level (doctorate, master, bachelor, vocational high school, high school, and others), and so $n=6$.

Calculation of education intensity index is explained step by step below.

- Firstly, the sum of the number of R&D personnel by education level is calculated for each manufacturing industry for each year. For example, in 2009, in manufacture of food products, total number of R&D personnel who have doctoral degree is calculated. This process is applied to other education levels, and to other manufacturing industries.

- Secondly, each total number of R&D personnel by education level is multiplied by its weighting factor (year of schooling/100)⁸⁵.
- Thirdly, for each manufacturing industry, the values of multiplication are summed up.
- Fourthly, for each industry, the sum of these values is divided by 0.9, in other words the sum of weighting factor values⁸⁶. Therefore, for each year and each manufacturing industry, weighted means are calculated.
- Fifthly, for each industry, average of weighted means for the period between 2009 and 2016 is calculated. For example, for the manufacture of food products, the average of annual weighted means is calculated. Then, each industry has its own average value of annual weighted means.
- Sixthly, the average values of annual weighted means by manufacturing industry are normalized by using the equation below, which is shown in Equation 44. Therefore, the values are brought into the range between 1 and 0, in other words [0,1].

$$x_{normalized} = \frac{x_{original} - x_{min}}{x_{max} - x_{min}} \quad (44)$$

- Finally, these normalized values of manufacturing industries are used in cluster analysis to classify the Turkish manufacturing industry by education intensity, which is shown in Appendix 3. This analysis separates the industry by education intensity index to reveal industries with high educated intensity, with medium-high educated intensity, with medium-low educated intensity, and with low educated intensity.

Partition-clustering methods (k-means and k-medians) are used for the cluster analysis that is conducted by using Stata program. Specifically, the k-means method is used to cluster Turkish manufacturing industry by education intensity for four

⁸⁵ In Türkiye, a person studies 22 year for a PhD degree, and lesser for other education levels. Year of schooling is used for weighting factor such as 0.22 for PhD, 0.18 for Master, 0.16 for Bachelor 0.14 for Vocational High School, 0.12 for High School, 0.8 for other levels.

⁸⁶ The sum of values of weighting factors is 0.9 (0.22+0.18+0.16+0.14+0.12+0.8)

groups ($k=4$). In this analysis, as starting centers for the k groups, k unique values are chosen randomly among the values of manufacturing industries (k -random option is default). In this analysis, L2 norm, in other words Euclidean distance, is used to measure distance, which is shown in Equation 45.

$$d((x_1, x_2, \dots, x_n), (y_1, y_2, \dots, y_n)) = \sqrt{\sum_{i=1}^n (x_i - y_i)^2} \quad (45)$$

In this dissertation, education intensity classification based on NACE Rev. 2 at 2-digit level is used for the analysis to reveal the importance of education in terms of likelihood of occurrence of product and process innovation, and to reveal the differences among the manufacturing industry by education intensity.

3.2.4.4. Firm Size (FS) Classification

Song and Oh (2015) suggested to study differences by firm size in terms of likelihood of occurrence of innovation. So, these differences are aimed to research in Turkish manufacturing industry. Then, Turkish manufacturing industry is classified by firm size.

Firms size classification, which is shown in Table 13, is significant to understand differences among micro, small, medium-sized, and large firms. The most common size measure to classify firms is the number of people employed and it is used instead of the others such as annual *turnover*, annual balance sheet total.

In this dissertation, firms are classified by their size with respect to number of employees. Specifically, firms that engaged in R&D and firms with 20 or more employees are analyzed by their size classification. In other words, only SMEs and large firms are included in the analysis.

Table 13: Firm Size Classification

	Firm Size			
	SMEs			Large
	Micro	Small	Medium	
Number of employees (n)	n<10	n<50	n<250	n>250

Source: European Commission, 2020.

In this chapter, research method and design are explained in detail. Research models and hypotheses are determined. Moreover, panel data, independent variables, and proxy variables are generated.

In the next chapter, descriptive statistics about the panel data, and the analysis of Turkish manufacturing industry by section C (as a whole) and by division (manufacturing industry separately) are interpreted.



CHAPTER FOUR

ANALYSIS OF TURKISH MANUFACTURING INDUSTRY BY SECTION AND DIVISION

In chapter I, the theoretical framework of the dissertation is provided by regarding R&D and innovation. In chapter II, the importance of S&T, R&D activities, and education is emphasized, and R&D statistics in detail in Türkiye is explained. In chapter III, research methodology and data are interpreted inclusively.

In this chapter, firstly, descriptive statistics is presented. Then, in the shadow of theoretical framework, research methodology, and research design, the results of the analysis of firms that engaged in R&D in Turkish manufacturing industry are presented from the perspectives of section C and division, except manufacture of tobacco products that does not have any R&D activities in this panel data. In terms of the other perspectives such as classifications by TI, EII, and FS, Turkish manufacturing industry is analyzed in the next chapter.

In this dissertation, firms that engaged in R&D in Turkish manufacturing industry are analyzed from the five perspectives such as analysis of the industry by section C (as a whole), by division (manufacturing industry separately), and by classifications in terms of TI, EII, and FS, to reveal the effect of independent variables on the likelihood of occurrence of product and process innovations. These independent variables are *total R&D expenditure*, *internal R&D expenditure*, *external R&D expenditure*, *external-domestic R&D expenditure*, *external-foreign R&D expenditure*, *total R&D intensity*, *internal R&D intensity*, *external R&D intensity*, *external-domestic R&D intensity*, and *external-foreign R&D intensity*, *R&D personnel intensity*, *turnover*, *Herfindahl-Hirschman Index (HHI)*, and *industrial production index by manufacturing industry*.

To analyze the firms, twenty research models are used, which are probit models with population-averaged estimator. These models are shown in detail in Table 3 that is in Chapter 3, and in Appendix 7, 8, 9, and 10. The probit model with population-

averaged estimator is used to analyze the panel data with binary dependent variables such as product (PD) and process (PC) innovation (if a firm introduces innovation—1, otherwise—0) with robust standard error method, within-unit exchangeable correlation structure (equal-correlation model), and confidence level 90 percent. To do this, panel data is generated from some micro data sets in A Group Data in TURKSTAT such as Annual Industry and Service Statistics (AISS), Research and Development Activities Surveys in Business Enterprise Sector (RDAS), Annual Industrial Products (PRODCOM) Statistics, and Innovation Survey (IS).

The hypotheses are mainly based on ‘more R&D expenditure more likelihood of occurrence of product and process innovation’ and ‘more R&D intensity more likelihood of occurrence of product and process innovation’ approach. These hypotheses are related to results of former studies in literature. For example, a positive relationship between R&D expenditure and innovative output (Acs and Audretsch, 1988a, 1988b; Audretsch and Vivarelli, 1996) and correlation between R&D intensity and firm’s inventive output (Mansfield, 1964) were found previously. Therefore, it is assumed that R&D expenditure and R&D intensity increase the likelihood of occurrence of product and process innovation.

Some other studies showed that there is a positive relationships between R&D expenditure and market structure and between R&D intensity (R&D expenditure/sales) and market structure (Hamberg, 1964), between the number of R&D personnel and product and process innovation (Song and Oh, 2015), and between process and product innovation performance and inventory turnover performance of the firm (Lee, Zhou, and Hsu, 2015). Therefore, it is assumed that other variables such as *R&D personnel intensity*, *turnover*, *Herfindahl-Hirschman Index (HHI)* are positively related to the likelihood of occurrence of innovation. Moreover, when business activity and production increase in the industry, economy becomes more active, and firms increase their turnovers. In this environment, firms can be motivated by this recovery and increase in turnover. Then, firms can be more propensity for introducing product and process innovation. Increase in *industrial production index by manufacturing industry* can cause to increase the likelihood of occurrence of product

and process innovation. It is also assumed that this variable is also positively related to the likelihood of occurrence of innovation.

4.1. Descriptive Statistics of the Panel Data

In this dissertation, the unbalanced panel data analysis of Turkish manufacturing industry covers 1219 firms that engaged in R&D activities and from twenty-three different sectors and eight years (the period between 2009 and 2016). 4155 observations with 20 or more employees are analyzed for the period between 2009 and 2016. Detailed descriptive statistics of dependent and independent variables such as mean, standard deviation, minimum and maximum values can be seen in Appendix 6.

Table 14: One-Way Table of Frequency Counts by Year

Year	Frequency	Percent	Cumulative
2009	287	6.91	6.91
2010	545	13.12	20.02
2011	532	12.8	32.83
2012	646	15.55	48.38
2013	478	11.5	59.88
2014	630	15.16	75.04
2015	497	11.96	87
2016	540	13	100
Total	4,155	100	

Source: Generated panel data by Author from TURKSTAT data sets.

One-way table of frequency counts of unbalanced panel data is important to understand the distribution of the observations in the panel data by year and by manufacturing industry. Table 14 shows one-way frequency counts by year. According to this table, half of the period includes approximately half of the observations. In more detail, there are 287 observations in 2009 that corresponds to 6.91% of total observations; 545 observations in 2010 (13.12% of total observations); 532 observations in 2011 (12.8%); 646 observations in 2012 (15.55%); 478 observations in 2013 (11.5%); 630 observations in 2014 (15.16%); 497 observations in 2015 (11.96%), and 540 observations in 2016 (13%), respectively.

Table 15: One-Way Table of Frequency Counts by Manufacturing Industry

NACE2	Frequency	Percent	Cumulative	Number of Firm
10	430	10.35	10.35	107
11	23	0.55	10.9	7
13	270	6.5	17.4	72
14	53	1.28	18.68	18
15	20	0.48	19.16	5
16	19	0.46	19.61	5
17	44	1.06	20.67	16
18	23	0.55	21.23	7
19	38	0.91	22.14	13
20	360	8.66	30.81	112
21	204	4.91	35.72	51
22	293	7.05	42.77	92
23	248	5.97	48.74	69
24	187	4.5	53.24	62
25	326	7.85	61.08	107
26	205	4.93	66.02	64
27	398	9.58	75.6	106
28	390	9.39	84.98	140
29	370	8.9	93.89	96
30	76	1.83	95.72	16
31	85	2.05	97.76	29
32	72	1.73	99.49	25
33	21	0.51	100	6
Total	4,155	100		1219

Source: Generated panel data by Author from TURKSTAT data sets.

Table 15 shows one-way frequency counts by NACE Rev.2 2-digit. It is seen that distribution of data is unbalanced because the number of firms that engaged in R&D is not same in every industry. Manufacturing industries with more than 8.5% of total observations (approximately 360-430 observations) are the first fifth of twenty-three industries respectively such as: 10-manufacture of food products; 27-manufacture of electrical equipment; 28-manufacture of machinery and equipment n.e.c.; 29-manufacture of motor vehicles, trailers and semi-trailers; and 20-manufacture of chemicals and chemical products. Manufacturing industries with less than 1% of total observations (approximately 40 observations) are last six of twenty-three industries such as: 19-manufacture of coke and refined petroleum products; 11-manufacture of beverages; 18-printing and reproduction of recorded media; 33-repair

and installation of machinery and equipment; 15-manufacture of leather and related products; 16-manufacture of wood and of products of wood and cork, except furniture, and manufacture of articles of straw and plaiting materials.

Turkish manufacturing industry is analyzed from five perspectives (as a whole, by industry, and classifications of TI, EII, and FS). One-way tables of frequency counts by years and manufacturing industry are viewed above, which are shown in Table 14 and 15. These are important to understand observations in terms of analysis as a whole and analysis by industry in detail. To understand observations in terms of classification perspectives (TI, EII, and FS), one-way tables of frequency counts by these classification, which are shown in Table 16, 17, and 18, and two-way tables of frequency counts by TI-EII, FS-TI, and EII-FS are viewed, which are shown in Table 19, 20, and 21.

According to one-way table of frequency counts by TI, which is shown in Table 16, half of the observations (approximately 48%) is in HT and MHT industries while the rest of them is in MLT and LT industries. The number of observations (409) in HT industries is relatively lower than others and represents approximately 10% of total observations. Most of observations (1594) are in MHT industries and represents approximately 38% of total observations. The number of observations in MLT and LT industries (1113 and 1039, respectively) represent approximately 27% and 25% of total observations, respectively.

Table 16: One-Way Table of Frequency Counts by Technology Intensity

Technology Intensity	Total	Percent	Cumulative
HT	409	9.84	9.84
MHT	1,594	38.36	48.21
MLT	1,113	26.79	74.99
LT	1,039	25.01	100
Total	4,155	100	

Source: Generated panel data by Author from TURKSTAT data sets. HT: High Technology; MHT: Medium-High Technology; MLT: Medium-Low Technology; and LT: Low Technology. Table is sorted by TI.

According to one-way table of frequency counts by EII, which is shown in Table 17, half of the observations (approximately 56%) are in industries with HEI and MHEI while the rest of them is in industries with MLEI and LEI. The number of observations (973) in industries with HEI represents approximately 23% of total observations (the second last). Most of observations (1356 and 1428) are in industries with MHEI and MLEI and represent approximately 33% and 34% of total observations, respectively, in other words approximately 67% of total observations.

Table 17: One-Way Table of Frequency Counts by Education Intensity

Education Intensity	Total	Percent	Cumulative
HEI	973	23.42	23.42
MHEI	1,356	32.64	56.05
MLEI	1,428	34.37	90.42
LEI	398	9.58	100
Total	4,155	100	

Source: Generated panel data by Author from TURKSTAT data sets. HEI: High Education Intensity; MHEI: Medium-High Education Intensity; MLEI: Medium-Low Education Intensity; LEI: Low Education Intensity. Table is sorted by EII.

According to one-way table of frequency counts by FS, which is shown in Table 18, approximately 41% of total observations comes from SMEs while the rest of the observations (approximately 59%) are from large firms. In more detail, approximately 21% of total observations (871) belongs to small firms and approximately 20% of total observations belongs to medium-sized firms.

Table 18: One-Way Table of Frequency Counts by Firm Size

Firm Size	Total	Percent	Cumulative
Small	871	20.96	20.96
Medium	830	19.98	40.94
Large	2,454	59.06	100
Total	4,155	100	

Source: Generated panel data by Author from TURKSTAT data sets.

Two-way tables of frequency counts by TI-EII, FS-TI, and EII-FS are obtained with a summary of the χ^2 test at the bottom of them, which are shown in Table 19, 20,

and 21. The χ^2 test shows Pearson's χ^2 that tests the hypothesis (H_0 : independence of rows and columns).

Table 19: Two-Way Table of Frequency Counts by TI and EII

Education Intensity	Technology Intensity				Total
	HT	MHT	MLT	LT	
HEI	205	768	0	0	973
MHEI	204	826	326	0	1,356
MLEI	0	0	728	700	1,428
LEI	0	0	59	339	398
Total	409	1,594	1,113	1,039	4,155

Pearson chi2(9) = 3700 Pr = 0.000

Source: Generated panel data by Author from TURKSTAT data sets.

The two-way table of frequency counts by TI-EII is significant to understand relationship among industries with respect to TI and EII, which is shown in Table 19. It is supposed to compare technology intensity distribution across education intensity. χ^2 associated with this two-way table has 9 degrees of freedom and is 3700. The observed differences in this table are significant at 1% level. According to the table, half of total observations (approximately 48%) comes from both manufacturing industries with HEI and MHEI, and HT and MHT manufacturing industries. Approximately 27% of total observations comes from MLT industries is also industries with MHEI, MLEI, and LEI. Moreover, LT industries (approximately 25% of total observations) are also industries with MLEI and LEI. These information about Turkish manufacturing industry shows other important results such as: there are no observations that are from both HT and MHT manufacturing industries, and the industries with MLEI and LEI; there are no observations that are from both MLT manufacturing industries, and the industries with HEI; and there are also no observations from both LT manufacturing industries and the industries with HEI and MHEI. It might be said that higher education intensity higher technology, relatively.

The two-way table of frequency counts by FS-TI is important to understand relationship among industries with respect to FS and TI, which is shown in Table 20. It is supposed to compare firm size distribution across technology intensity. χ^2 associated with this two-way table has 6 degrees of freedom and is 125.54. The

observed differences in this table are significant at 1% level. According to the table, most of the observations (888) comes from large firms in MHT industries and represent approximately 21% of total observations. Observations of large firms in LT (721) and MLT (680) industries represent approximately 17% and 16% of total observations. The number of observations of small firms in HT industries, and of medium-sized firms in HT industries, and of medium-sized firms in LT industries are so close each other and each of them represents approximately 3% of total observations. Most of the observations of small firms (approximately two-third), most of the observations of medium-sized firms (approximately two-third), and most of the observations of large firms (more than half) are in MHT and MLT manufacturing industries.

Table 20: Two-Way Table of Frequency Counts by FS and TI

Technology Intensity	Firm Size			Total
	Small	Medium	Large	
HT	122	122	165	409
MHT	341	365	888	1,594
MLT	216	217	680	1,113
LT	192	126	721	1,039
Total	871	830	2,454	4,155

Pearson chi2(6) = 125.5410 Pr = 0.000

Source: Generated panel data by Author from TURKSTAT data sets.

The two-way table of frequency counts by EII-FS is significant to understand relationship among industries with respect to EII and FS, which is shown in Table 21. It is supposed to compare education intensity distribution across firm size. The χ^2 associated with this two-way table has 6 degrees of freedom and is 165.16. The observed differences in this table are significant at 1% level. According to the table, most of the observations (1008) comes from large firms in industries with MLEI and represent approximately 25% of total observations. Observations (641) come from large firms in industries with MHEI and represent approximately 15% of total observations. Observations (574) comes from large firms in industries with HEI and represent approximately 14% of total observations. The number of observations of comes from small firms in manufacturing industries with HEI and MLEI, and of

medium-sized firms in the industries with HEI and MLEI, and of large firms in the industries with LEI are so close each other and each of them represents approximately 5% of total observations. Most of the observations of small firms (approximately two-third), most of the observations of medium-sized firms (approximately two-third), and most of the observations of large firms (approximately two-third) are in manufacturing industries with MHEI and MLEI. Moreover, SMEs represent more than half of observations that comes from the industries with MHEI (approximately 17% of total observations), less than half of the observations that comes from industries with HEI (approximately 10% of total observations), approximately one-third of the industries with MLEI (approximately 10% of total observations), and almost half of observations that comes from the industries with LEI (approximately 4% of total observations).

Table 21: Two-Way Table of Frequency Counts by EII and FS

Firm Size	Education Intensity				Total
	HEI	MHEI	MLEI	LEI	
Small	194	350	228	99	871
Medium	205	365	192	68	830
Large	574	641	1,008	231	2,454
Total	973	1,356	1,428	398	4,155

Pearson chi2(6) = 165.1563 Pr = 0.000

Source: Generated panel data by Author from TURKSTAT data sets.

One-way tabulations of product and process innovation decomposes their counts into between and within components in the panel data, which are shown in Table 22 and 23, respectively.

Table 22: One-Way Tabulations of Product Innovation

Product Innovation (PD)	Overall		Between		Within
	Frequency	Percent	Frequency	Percent	Percent
0	1101	26.5	507	41.59	77.19
1	3054	73.5	916	75.14	90.36
Total	4155	100	1423	116.74	85.66

Source: Generated panel data by Author from TURKSTAT data sets. n=1219.

According to one-way tabulations of product innovation, which is shown in Table 22, the overall part of the table summarizes results in terms of firm-years. There

are 1101 firm-years of data in which introducing PD is 0 and 3054 in which PD is 1. In other words, in 73.5% of the panel data, the firm introduced product innovation in last three years. The between part of the table repeats the breakdown, but this time in terms of firm rather than firm-years; 507 of firms ever had PD 0 (approximately 42%) and 916 firms ever had PD 1 (approximately 75%), for a grand total of 1423 ever having either. There are only 1219 firms in the panel data. It means that there are firms that sometimes have PD 0 and at other times have PD 1. The within percent in the table shows the fraction of the time a firm has the specified value of PD. Conditional on a firm ever having PD 0, 77.2% of its observations have PD 0 while conditional on a firm ever having PD 1, 90.4% of its observations have PD 1. These two indicators are a measure of the stability of the PD values. According to this measure, PD 1 is more stable among these innovative firms than PD 0, meaning that these firms tend to innovate more. The total within 85.66% is the measure of the overall stability of PD variable.

Table 23: One-Way Tabulations of Process Innovation

Process Innovation (PC)	Overall		Between		Within
	Frequency	Percent	Frequency	Percent	Percent
0	1004	24.16	482	39.54	75.65
1	3151	75.84	942	77.28	90.7
Total	4155	100	1424	116.82	85.6

Source: Generated panel data by Author from TURKSTAT data sets. n=1219.

According to one-way tabulations of process innovation, which is shown in Table 23, the overall part of the table summarizes results in terms of firm-years. There are 1104 firm-years of data in which introducing PC is 0 and 3151 in which PC is 1. In other words, in 75.84% of the panel data, the firm introduced process innovation in last three years. The between part of the table repeats the breakdown, but this time in terms of firm rather than firm-years; 482 of firms ever had PC 0 (approximately 40%) and 942 firms ever had PC 1 (approximately 77%), for a grand total of 1424 ever having either. There are only 1219 firms in the panel data. It means that there are firms that sometimes have PC 0 and at other times have PC 1. The within percent in the table shows the fraction of the time a firm has the specified value of PC. Conditional on a

firm ever having PC 0, 75.7% of its observations have PC 0 while conditional on a firm ever having PC 1, 90.7% of its observations have PC 1. These two indicators are a measure of the stability of PC values. According to this measure, PC 1 is more stable among these innovative firms than PC 0, meaning that these firms tend to innovate more. The total within 85.6% is the measure of the overall stability of PC variable.

Transition possibilities are also important to understand firms and the panel data more, which are shown in Table 24 and 25. It explains the change in product innovation (binary variable) over time.

Table 24: Transition Possibilities of Product Innovation

Product Innovation (PD)	Product Innovation (PD)		Total
	0	1	
0	81.5	18.5	100
1	5.28	94.72	100
Total	23.94	76.06	100

Source: Generated panel data by Author from TURKSTAT data sets.

According to transition possibilities of product innovation, which is shown in Table 24, each year, some 81.5% of PD 0 firms in the panel data remained PD 0 in the next year; the remaining 18.5% became PD 1. Although PD 0 had an 18.5% chance of becoming PD 1 in each year, the PD 1 had only a 5.28% chance of becoming PD 0. Each year, some 94.7% of PD 1 firms remained PD 1 in the next year.

Table 25: Transition Possibilities of Process Innovation

Process Innovation (PD)	Process Innovation (PD)		Total
	0	1	
0	78.29	21.71	100
1	5.21	94.79	100
Total	21.49	78.51	100

Source: Generated panel data by Author from TURKSTAT data sets.

According to transition possibilities of process innovation, which is shown in Table 25, each year, some 78.29% of PC 0 firms in the panel data remained PC 0 in

the next year; the remaining 21.71% became PC 1. Although PC 0 had a 21.71% chance of becoming PC 1 in each year, the PC 1 had only a 5.21% chance of becoming PC 0. Each year, some 94.8% of PC 1 firms remained PC 1 in the next year.

4.2. Turkish Manufacturing Industry Analysis – Section C and Division

Firms that are engaged in R&D in Turkish manufacturing industry is analyzed from two perspectives here such as section (as a whole) and division (by industry), except manufacture of tobacco products because it does not have any R&D activities in this panel data.

4.2.1. Turkish Manufacturing Industry Analysis by Section C

The analysis of all Turkish manufacturing industry together (as a whole perspective), known as the analysis of section C in NACE Rev. 2, includes all manufacturing industries, except manufacture of tobacco products.

Firms that are engaged in R&D in Turkish manufacturing industry are analyzed by section C (as a whole) with twenty models such as 10 product innovation models and 10 process innovation models, which are shown in Table 3 that is in Chapter 3 and in Appendix 7, 8, 9, and 10.

Regression results of PDRE1 and PCRE1 models include coefficient, p-value, and average marginal effect, which are shown in Table 26. These models analyze the effect of *total R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE1 model focuses on the relationship between product innovation and *total R&D expenditure*, which is shown in Table 26. In this model, independent variables are not statistically significant at 10% level, except *total R&D expenditure*. *Total R&D expenditure* is statistically significant at 1% level. Hence, the null hypothesis, $H1_0$, is rejected. It means that 1 percent increase in the value of *total R&D expenditure*, on average, leads to an increase of 0.7 percent in the likelihood of occurrence of product innovation (to take the value of 1) in Turkish manufacturing industry.

Table 26: Regression Results of PDRE1 and PCRE1 Models – As A Whole

Variable Name	PDRE1			PCRE1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntrdexpD</i>	0.1293	0.000 ***	0.0071	0.0980	0.000 ***	0.0298
<i>rdperint</i>	0.1056	0.635	0.0346	0.4105	0.075 *	0.1247
<i>IntoverD</i>	0.0159	0.563	0.0052	0.1195	0.000 ***	0.0363
<i>HHI</i>	0.5464	0.304	0.1790	0.7580	0.082 *	0.2302
<i>phd_ma</i>	0.0022	0.248	0.0007	0.0001	0.852	0.0000
<i>ipicsec</i>	0.0008	0.246	0.0003	0.0026	0.001 ***	0.0008

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE1: Wald chi2(6)=66.29 Prob > chi2=0.0000

For PCRE1: Wald chi2(6)=116.83 Prob > chi2=0.0000

The PCRE1 model focuses on the relationship between process innovation and *total R&D expenditure*, which is shown in Table 26. In this model, some independent variables such as *total R&D expenditure*, *turnover*, and *industrial production index by manufacturing industry* are statistically significant at 1% level, and some of them such as *R&D personnel intensity* and *HHI* are statistically significance at 10% level. Hence, the null hypothesis, H_{30} , is rejected. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *total R&D expenditure*, on average, leads to an increase of 3 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 3.6 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.08 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.12 in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 0.23 in the likelihood of occurrence of process innovation.

Regression results of PDRE2 and PCRE2 models include coefficient, p-value, and average marginal effect, which are shown in Table 27. These models analyze the effect of *internal R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE2 model focuses on the relationship between product innovation and *internal R&D expenditure*, which is shown in Table 27. In this model, independent variables are not statistically significant at 10% level, except *internal R&D expenditure*. *Internal R&D expenditure* is statistically significant at 1% level. Hence, the null hypothesis, $H1a_0$, is rejected. It means that 1 percent increase in the value of *internal R&D expenditure*, on average, leads to an increase of 4.2 percent in the likelihood of occurrence of product innovation (to take the value of 1) in Turkish manufacturing industry.

Table 27: Regression Results of PDRE2 and PCRE2 Models – As A Whole

Variable Name	PDRE2			PCRE2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntintrdexpD</i>	0.1294	0.000 ***	0.0424	0.0987	0.000 ***	0.0300
<i>rdperint</i>	0.1035	0.642	0.0339	0.4063	0.078 *	0.1234
<i>IntoverD</i>	0.0161	0.559	0.0053	0.1193	0.000 ***	0.0362
<i>HHI</i>	0.5519	0.299	0.1809	0.7608	0.081 *	0.2311
<i>phd_ma</i>	0.0022	0.246	0.0007	0.0001	0.863	0.0000
<i>ipicsec</i>	0.0008	0.250	0.0003	0.0026	0.001 ***	0.0008

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE2: Wald $\chi^2(6)=65.69$ Prob > $\chi^2=0.0000$

For PCRE2: Wald $\chi^2(6)=116.74$ Prob > $\chi^2=0.0000$

The PCRE2 model focuses on the relationship between process innovation and *internal R&D expenditure*, which is shown in Table 27. In this model, some independent variables such as *internal R&D expenditure*, *turnover*, and *industrial production index by manufacturing industry* are statistically significant at 1% level, and some of them such as *R&D personnel intensity* and *HHI* are statistically significance at 10% level. Hence, the null hypothesis, $H3a_0$, is rejected. Moreover, the *number of highly educated R&D personnel* is not statistically significant at 10% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *internal R&D expenditure*, on average, leads to an increase of 3 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 3.6 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.08 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.12 in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 0.23 in the likelihood of occurrence of process innovation.

Regression results of PDRE3 and PCRE3 models include coefficient, p-value, and average marginal effect, which are shown in Table 28. These models analyze the effect of *external R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE3 model focuses on the relationship between product innovation and *external R&D expenditure*, which is shown in Table 28. In this model, *turnover* is statistically significant at 1% level. Some independent variables such as *external R&D expenditure* and *R&D personnel intensity* are statistically significant at 5% level, and such as number of high educated R&D personnel and *industrial production index by manufacturing industry* are statistically significant at 10% level. Hence, the null hypothesis, $H1b_0$, is rejected. Moreover, *HHI* is not statistically significant at 10% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 2.8 percent in the likelihood of occurrence of product innovation.

- 1 percent increase in the value of *external R&D expenditure*, on average, leads to an increase of 0.3 percent in the likelihood of occurrence of product innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.22 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.24 percent in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.04 percent in the likelihood of occurrence of product innovation.

Table 28: Regression Results of PDRE3 and PCRE3 Models – As A Whole

Variable Name	PDRE3			PCRE3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpD</i>	0.0095	0.044 **	0.0032	0.0014	0.799	0.0004
<i>rdperint</i>	0.6438	0.012 **	0.2156	0.8857	0.001 ***	0.2732
<i>IntoverD</i>	0.0845	0.000 ***	0.0283	0.1769	0.000 ***	0.0546
<i>HHI</i>	0.5479	0.330	0.1835	0.7699	0.096 *	0.2375
<i>phd_ma</i>	0.0071	0.062 *	0.0024	0.0028	0.276	0.0009
<i>ipicsec</i>	0.0013	0.076 *	0.0004	0.0029	0.000 ***	0.0009

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE3: Wald chi2(6)=29.68 Prob > chi2=0.0000

For PCRE3: Wald chi2(6)=90.60 Prob > chi2=0.0000

The PCRE3 model focuses on the relationship between process innovation and *external R&D expenditure*, which is shown in Table 28. In this model, some independent variables such as *R&D personnel intensity*, *turnover*, and *industrial production index by manufacturing industry* are statistically significant at 1% level. Moreover, *HHI* is statistically significant at 10% level. However, the *number of highly educated R&D personnel* and *external R&D expenditure* is not statistically significant at 10% level. Hence, the null hypothesis, $H3b_0$, is not rejected. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.27 in the likelihood of occurrence of process innovation.

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.5 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.09 percent in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 0.24 in the likelihood of occurrence of process innovation.

Regression results of PDRE4 and PCRE4 models include coefficient, p-value, and average marginal effect, which are shown in Table 29. These models analyze the effect of *external-domestic R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE4 model focuses on the relationship between product innovation and *external-domestic R&D expenditure*, which is shown in Table 29. In this model, *turnover* is statistically significant at the 1% level. *R&D personnel intensity* is statistically significant at 5% level. Some independent variables such as *external-domestic R&D expenditure*, the *number of highly educated R&D personnel*, and *industrial production index by manufacturing industry* are statistically significant at 10% level. Hence, the null hypothesis, $H1c_0$, is rejected. Moreover, *HHI* is not statistically significant at the 10% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 2.85 percent in the likelihood of occurrence of product innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.22 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *external-domestic R&D expenditure*, on average, leads to an increase of 0.28 percent in the likelihood of occurrence of product innovation.

- 1 percent increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.24 percent in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.04 percent in the likelihood of occurrence of product innovation.

Table 29: Regression Results of PDRE4 and PCRE4 Models – As A Whole

Variable Name	PDRE4			PCRE4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpdomD</i>	0.0084	0.079 *	0.0028	-0.0016	0.772	-0.0005
<i>rdperint</i>	0.6482	0.012 **	0.2173	0.8938	0.001 ***	0.2758
<i>IntoverD</i>	0.0849	0.000 ***	0.0285	0.1777	0.000 ***	0.0548
<i>HHI</i>	0.5509	0.327	0.1846	0.7734	0.095 *	0.2387
<i>phd_ma</i>	0.0072	0.057 *	0.0024	0.0029	0.269	0.0009
<i>ipicsec</i>	0.0012	0.083 *	0.0004	0.0029	0.000 ***	0.0009

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE4: Wald chi2(6)=28.34 Prob > chi2=0.0001

For PCRE4: Wald chi2(6)=89.46 Prob > chi2=0.0000

The PCRE4 model focuses on the relationship between process innovation and *external-domestic R&D expenditure*, which is shown in Table 29. In this model, some independent variables such as *R&D personnel intensity*, *turnover*, and *industrial production index by manufacturing industry* are statistically significant at 1% level. Moreover, *HHI* is statistically significant at 10% level. However, the *number of highly educated R&D personnel* and *external R&D expenditure* is not statistically significant at 10% level. Hence, the null hypothesis, $H3c_0$, is not rejected. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.28 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.5 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.09 percent in the likelihood of occurrence of process innovation.

- An increase in *HHI* of 0.01, on average, leads to an increase of 0.24 in the likelihood of occurrence of process innovation.

Regression results of PDRE5 and PCRE5 models include coefficient, p-value, and average marginal effect, which are shown in Table 30. These models analyze the effect of *external-foreign R&D expenditure* on the probability of product and process innovations, respectively.

Table 30: Regression Results of PDRE5 and PCRE5 Models – As A Whole

Variable Name	PDRE5			PCRE5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpforD</i>	0.0115	0.221	0.0039	0.0250	0.021 **	0.0077
<i>rdperint</i>	0.6589	0.010 **	0.2207	0.8682	0.001 ***	0.2670
<i>IntoverD</i>	0.0857	0.000 ***	0.0287	0.1734	0.000 ***	0.0533
<i>HHI</i>	0.5804	0.289	0.1944	0.7515	0.102	0.2311
<i>phd_ma</i>	0.0071	0.066 *	0.0024	0.0024	0.301	0.0007
<i>ipicsec</i>	0.0012	0.082 *	0.0004	0.0030	0.000 ***	0.0009

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE5: Wald chi2(6)=26.02 Prob > chi2=0.0002

For PCRE5: Wald chi2(6)=98.88 Prob > chi2=0.0000

The PDRE5 model focuses on the relationship between product innovation and *external-foreign R&D expenditure*, which is shown in Table 30. In this model, *turnover* is statistically significant at 1% level. *R&D personnel intensity* is statistically significant at 5% level. Some independent variables such as the *number of highly educated R&D personnel* and *industrial production index by manufacturing industry* are statistically significant at 10% level. However, *external-foreign R&D expenditure* is not statistically significant at 10% level. Hence, the null hypothesis, $H1d_0$, is not rejected. Moreover, *HHI* is not statistically significant at 10% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 2.87 percent in the likelihood of occurrence of product innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.22 in the likelihood of occurrence of product innovation.

- 1 percent increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.24 percent in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.04 percent in the likelihood of occurrence of product innovation.

The PCRE5 model focuses on the relationship between process innovation and *external-foreign R&D expenditure*, which is shown in Table 30. In this model, some independent variables such as *R&D personnel intensity*, *turnover*, and *industrial production index by manufacturing industry* are statistically significant at 1% level. *External-foreign R&D expenditure* is statistically significant at the 5% level. Hence, the null hypothesis, $H3d_0$, is rejected. Moreover, *HHI* and the *number of highly educated R&D personnel* is not statistically significant at 10% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.27 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.33 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.09 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *external-foreign R&D expenditure*, on average, leads to an increase of 0.77 percent in the likelihood of occurrence of process innovation.

Regression results of PDRI1 and PCRI1 models include coefficient, p-value, and average marginal effect, which are shown in Table 31. These models analyze the effect of *total R&D intensity* on the probability of product and process innovations, respectively.

Table 31: Regression Results of PDRI1 and PCRI1 Models – As A Whole

Variable Name	PDRI1			PCRI1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>totrdint</i>	0.7958	0.089 *	0.2660	0.4796	0.160	0.1476
<i>rdperint</i>	0.4118	0.209	0.1377	0.6690	0.048 **	0.2058
<i>IntoverD</i>	0.0942	0.000 ***	0.0315	0.1816	0.000 ***	0.0559
<i>HHI</i>	0.5895	0.294	0.1971	0.7945	0.087 *	0.2445
<i>phd_ma</i>	0.0067	0.063 *	0.0023	0.0025	0.300	0.0008
<i>ipicsec</i>	0.0012	0.095 *	0.0004	0.0029	0.000 ***	0.0009

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI1: Wald $\chi^2(6) = 24.88$ Prob > $\chi^2 = 0.0004$

For PCRI1: Wald $\chi^2(6) = 89.81$ Prob > $\chi^2 = 0.0000$

The PDRI1 model focuses on the relationship between product innovation and *total R&D intensity*, which is shown in Table 31. In this model, *turnover* is statistically significant at 1% level. Some independent variables such as *total R&D intensity*, the *number of highly educated R&D personnel*, and *industrial production index by manufacturing industry* are statistically significant at 10% level. Hence, the null hypothesis, H_{20} , is rejected. However, *R&D personnel intensity* and *HHI* is not statistically significant at 10% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 3.15 percent in the likelihood of occurrence of product innovation.
- A unit increase in the value of *total R&D intensity*, on average, leads to an increase of 0.27 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.23 percent in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.04 percent in the likelihood of occurrence of product innovation.

The PCRI1 model focuses on the relationship between process innovation and *total R&D intensity*, which is shown in Table 31. In this model, some independent variables such as *turnover* and *industrial production index by manufacturing industry*

are statistically significant at 1% level. *R&D personnel intensity* is statistically significant at 5% level. *HHI* is statistically significant at 10% level. However, *total R&D intensity* and the *number of highly educated R&D personnel* are not statistically significant at 10% level. Hence, the null hypothesis, H_{40} , is not rejected. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.59 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.09 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.21 in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 0.24 in the likelihood of occurrence of process innovation.

Regression results of PDRI2 and PCRI2 models include coefficient, p-value, and average marginal effect, which are shown in Table 32. These models analyze the effect of *internal R&D intensity* on the probability of product and process innovations, respectively.

Table 32: Regression Results of PDRI2 and PCRI2 Models – As A Whole

Variable Name	PDRI2			PCRI2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>intrdint</i>	0.8172	0.122	0.2733	0.4265	0.242	0.1313
<i>rdperint</i>	0.4164	0.214	0.1392	0.6992	0.044 **	0.2152
<i>IntoverD</i>	0.0939	0.000 ***	0.0314	0.1810	0.000 ***	0.0557
<i>HHI</i>	0.5922	0.293	0.1980	0.7945	0.088 *	0.2446
<i>phd_ma</i>	0.0067	0.062 **	0.0023	0.0025	0.293	0.0008
<i>ipicsec</i>	0.0012	0.097 *	0.0004	0.0029	0.000 ***	0.0009

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI2: Wald chi2(6)=24.72 Prob > chi2=0.0004

For PCRI2: Wald chi2(6)=89.73 Prob > chi2=0.0000

The PDRI2 model focuses on the relationship between product innovation and *internal R&D intensity*, which is shown in Table 32. In this model, *turnover* is

statistically significant at 1% level. The *number of highly educated R&D personnel* statistically significant at 5% level. *Industrial production index by manufacturing industry* is statistically significant at 10% level. However, *internal R&D intensity*, *R&D personnel intensity*, and *HHI* are not statistically significant at 10% level. Hence, the null hypothesis, $H2a_0$, is not rejected. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 3.14 percent in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.23 percent in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.04 percent in the likelihood of occurrence of product innovation.

The PCRI2 model focuses on the relationship between process innovation and *internal R&D intensity*, which is shown in Table 32. In this model, some independent variables such as *turnover* and *industrial production index by manufacturing industry* are statistically significant at 1% level. *R&D personnel intensity* is statistically significant at 5% level. *HHI* is statistically significant at 10% level. However, *internal R&D intensity* and the *number of highly educated R&D personnel* are not statistically significant at 10% level. Hence, the null hypothesis, $H4a_0$, is not rejected. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.57 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.09 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.22 in the likelihood of occurrence of process innovation.

- An increase in *HHI* of 0.01, on average, leads to an increase of 0.24 in the likelihood of occurrence of process innovation.

Regression results of PDRI3 and PCRI3 models include coefficient, p-value, and average marginal effect, which are shown in Table 33. These models analyze the effect of *external R&D intensity* on the probability of product and process innovations, respectively.

Table 33: Regression Results of PDRI3 and PCRI3 Models – As A Whole

Variable Name	PDRI3			PCRI3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extrdint</i>	1.0180	0.002 ***	0.3413	2.0528	0.000 ***	0.6324
<i>rdperint</i>	0.6238	0.016 **	0.2092	0.8281	0.002 ***	0.2551
<i>IntoverD</i>	0.0875	0.000 ***	0.0293	0.1786	0.000 ***	0.0550
<i>HHI</i>	0.5737	0.303	0.1924	0.7783	0.093 *	0.2397
<i>phd_ma</i>	0.0075	0.049 **	0.0025	0.0028	0.273	0.0009
<i>ipicsec</i>	0.0012	0.087 *	0.0004	0.0029	0.000 ***	0.0009

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI3: Wald chi2(6)=33.39 Prob > chi2=0.0000

For PCRI3: Wald chi2(6)=97.94 Prob > chi2=0.0000

The PDRI3 model focuses on the relationship between product innovation and *external R&D intensity*, which is shown in Table 33. In this model, some independent variables such as *external R&D intensity* and *turnover* are statistically significant at 1% level. Hence, the null hypothesis, H_{2b0} , is rejected. Moreover, *R&D personnel intensity* and the *number of highly educated R&D personnel* statistically significant at 5% level. *Industrial production index by manufacturing industry* is statistically significant at 10% level. However, *HHI* are not statistically significant at 10% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external R&D intensity*, on average, leads to an increase of 0.34 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 2.93 percent in the likelihood of occurrence of product innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.21 in the likelihood of occurrence of product innovation.

- 1 percent increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.25 percent in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.04 percent in the likelihood of occurrence of product innovation.

The PCRI3 model focuses on the relationship between process innovation and *external R&D intensity*, which is shown in Table 33. In this model, some independent variables such as *external R&D intensity*, *R&D personnel intensity*, *turnover*, and *industrial production index by manufacturing industry* are statistically significant at 1% level. Hence, the null hypothesis, $H4b_0$, is rejected. Moreover, *HHI* is statistically significant at 10% level. However, the *number of highly educated R&D personnel* are not statistically significant at 10% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external R&D intensity*, on average, leads to an increase of 0.63 in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.26 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.5 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.09 percent in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 0.24 in the likelihood of occurrence of process innovation.

Regression results of PDRI4 and PCRI4 models include coefficient, p-value, and average marginal effect, which are shown in Table 34. These models analyze the

effect of *external-domestic R&D intensity* on the probability of product and process innovations, respectively.

Table 34: Regression Results of PDRI4 and PCRI4 Models – As A Whole

Variable Name	PDRI4			PCRI4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extdomrdint</i>	0.8117	0.002 ***	0.2722	1.4510	0.001 ***	0.4472
<i>rdperint</i>	0.6283	0.015 **	0.2107	0.8343	0.002 ***	0.2571
<i>lntoverD</i>	0.0873	0.000 ***	0.0293	0.1782	0.000 ***	0.0549
<i>HHI</i>	0.5727	0.304	0.1921	0.7758	0.094 *	0.2391
<i>phd_ma</i>	0.0075	0.047 **	0.0025	0.0029	0.266	0.0009
<i>ipicsec</i>	0.0012	0.088 *	0.0004	0.0029	0.000 ***	0.0009

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI4: Wald chi2(6)=34.59 Prob > chi2=0.0000

For PCRI4: Wald chi2(6)=94.09 Prob > chi2=0.0000

The PDRI4 model focuses on the relationship between product innovation and *external-domestic R&D intensity*, which is shown in Table 34. In this model, some independent variables such as *external-domestic R&D intensity* and *turnover* are statistically significant at 1% level. Hence, the null hypothesis, H_{2c0} , is rejected. Moreover, *R&D personnel intensity* and the *number of highly educated R&D personnel* statistically significant at 5% level. *Industrial production index by manufacturing industry* is statistically significant at 10% level. However, *HHI* are not statistically significant at 10% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external-domestic R&D intensity*, on average, leads to an increase of 0.27 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 2.93 percent in the likelihood of occurrence of product innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.21 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.25 percent in the likelihood of occurrence of product innovation.

- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.04 percent in the likelihood of occurrence of product innovation.

The PCRI4 model focuses on the relationship between process innovation and *external-domestic R&D intensity*, which is shown in Table 34. In this model, some independent variables such as *external-domestic R&D intensity*, *R&D personnel intensity*, *turnover*, and *industrial production index by manufacturing industry* are statistically significant at 1% level. Hence, the null hypothesis, $H4c_0$, is rejected. Moreover, *HHI* is statistically significant at 10% level. However, the *number of highly educated R&D personnel* are not statistically significant at 10% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external-domestic R&D intensity*, on average, leads to an increase of 0.45 in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.26 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.5 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.09 percent in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 0.24 in the likelihood of occurrence of process innovation.

Regression results of PDRI5 and PCRI5 models include coefficient, p-value, and average marginal effect, which are shown in Table 35. These models analyze the effect of *external-foreign R&D intensity* on the probability of product and process innovations, respectively.

The PDRI5 model focuses on the relationship between product innovation and *external-foreign R&D intensity*, which is shown in Table 35. In this model, *turnover*

is statistically significant at the 1% level. Some independent variables such as *external-foreign R&D intensity* and *R&D personnel intensity* are statistically significant at 5% level. Hence, the null hypothesis, $H2d_0$, is rejected. Moreover, the *number of highly educated R&D personnel* and *industrial production index by manufacturing industry* are statistically significant at 10% level. However, *HHI* are not statistically significant at 10% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 2.92 percent in the likelihood of occurrence of product innovation.
- A unit increase in the value of *external-foreign R&D intensity*, on average, leads to an increase of 1.61 in the likelihood of occurrence of product innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.22 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.25 percent in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.04 percent in the likelihood of occurrence of product innovation.

Table 35: Regression Results of PDRI5 and PCRI5 Models – As A Whole

Variable Name	PDRI5			PCRI5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extfrgrdint</i>	4.8096	0.043 **	1.6130	27.5348	0.025 **	8.4689
<i>rdperint</i>	0.6599	0.010 **	0.2213	0.8888	0.001 ***	0.2734
<i>IntoverD</i>	0.0871	0.000 ***	0.0292	0.1785	0.000 ***	0.0549
<i>HHI</i>	0.5710	0.305	0.1915	0.7722	0.094 *	0.2375
<i>phd_ma</i>	0.0074	0.050 *	0.0025	0.0028	0.272	0.0009
<i>ipicsec</i>	0.0012	0.090 *	0.0004	0.0029	0.000 ***	0.0009

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI5: Wald $\chi^2(6)=28.66$ Prob > $\chi^2=0.0001$

For PCRI5: Wald $\chi^2(6)=96.15$ Prob > $\chi^2=0.0000$

The PCRI5 model focuses on the relationship between process innovation and *external-foreign R&D intensity*, which is shown in Table 35. In this model, some independent variables such as *R&D personnel intensity*, *turnover*, and *industrial production index by manufacturing industry* are statistically significant at 1% level. *External-domestic R&D intensity* is statistically significant at 5% level. Hence, the null hypothesis, $H4d_0$, is rejected. Moreover, *HHI* is statistically significant at the 10% level. However, the *number of highly educated R&D personnel* are not statistically significant at 10% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.27 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.5 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.09 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of *external-foreign R&D intensity*, on average, leads to an increase of 8.46 in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 0.24 in the likelihood of occurrence of process innovation.

The results of the analyses in terms of product innovation are summarized in Appendix 11. Firstly, from the perspective of section C (all manufacturing industry analysis), it is seen that R&D expenditure variables and R&D intensity variables are statistically significant except PDRE5 model and PDRI2 model. In other words, *total R&D expenditure*, *internal R&D expenditure*, *external R&D expenditure*, *external-domestic R&D expenditure*, *total R&D intensity*, *external R&D intensity*, *external-domestic R&D intensity*, and *external-foreign R&D intensity* are statistically significant. For example, *ceteris paribus*: A 1 percent increase in the value of *total*

R&D expenditure, on average, leads to an increase of 0.71 percent in the likelihood of occurrence of product innovation; and A unit increase in the value of *total R&D intensity*, on average, leads to an increase of 0.27 in the likelihood of occurrence of product innovation. As a summary in terms of product innovation there are many findings such as:

- R&D expenditure variables such as total, internal, external, and external-domestic (PDRE1, PDRE2, PDRE3, and PDRE4 models, respectively) have positive effects on the likelihood of occurrence of product innovation in Turkish manufacturing industry. The most effective R&D expenditure type on the likelihood of occurrence of product innovation is *internal R&D expenditure*. For example, a 1 percent increase in the value of *internal R&D expenditure*, on average, leads to an increase of 4.24 percent in the likelihood of occurrence of product innovation.
- R&D intensity variables such as total, external, external-domestic, external-foreign (PDRI1, PDRI3, PDRI4, and PDRI5 models, respectively) have positive effects on the likelihood of occurrence of product innovation in Turkish manufacturing industry. The most effective R&D intensity type on the likelihood of occurrence of product innovation is *external-foreign R&D intensity*. For example, a unit increase in the value of *external-foreign R&D intensity*, on average, leads to an increase of 1.61 in the likelihood of occurrence of product innovation.
- The other independent variables are interpreted by focusing on the PDRE1 and PDRI1 models. Because these models cover *total R&D expenditures*. The other independent variables are not statistically significant at 10% level in PDRE1 model in terms of their effects on the likelihood of occurrence of product innovation in Turkish manufacturing industry. However, in PDRI1 model, they are statistically significant except *R&D personnel intensity* and *HHI*. It means that *turnover*, the *number of highly educated R&D personnel*, and *industrial production index by manufacturing*

industry have positive effect on the likelihood of occurrence of product innovation in Turkish manufacturing industry.

The results of the analyses in terms of process innovation are summarized in Appendix 12. Firstly, from the perspective of section C (all manufacturing industry analysis), it is seen that R&D expenditure variables and R&D intensity variables are statistically significant except PCRE5 model and PCRI2 model. In other words, *total R&D expenditure*, *internal R&D expenditure*, *external R&D expenditure*, *external-domestic R&D expenditure*, *total R&D intensity*, *external R&D intensity*, *external-domestic R&D intensity*, and *external-foreign R&D intensity* are statistically significant. For example, *ceteris paribus*: A 1 percent increase in the value of *total R&D expenditure*, on average, leads to an increase of 2.98 percent in the likelihood of occurrence of process innovation; and A unit increase in the value of *external R&D intensity*, on average, leads to an increase of 0.63 in the likelihood of occurrence of process innovation. As a summary in terms of process innovation there are many findings such as:

- R&D expenditure variables such as total, internal, external, and external-foreign (PDRE1, PDRE2, PDRE3, and PDRE5 models, respectively) have positive effects on the likelihood of occurrence of process innovation in Turkish manufacturing industry. The most effective R&D expenditure type on the likelihood of occurrence of process innovation is *internal R&D expenditure*. For example, a 1 percent increase in the value of *internal R&D expenditure*, on average, leads to an increase of 3 percent in the likelihood of occurrence of process innovation.
- R&D intensity variables such as external, external-domestic, external-foreign (PDRI3, PDRI4, and PDRI5 models, respectively) have positive effects on the likelihood of occurrence of process innovation in Turkish manufacturing industry. The most effective R&D intensity type on the likelihood of occurrence of process innovation is *external-foreign R&D intensity*. For example, a unit increase in the value of *external-foreign R&D intensity*.

intensity, on average, leads to an increase of 8.47 in the likelihood of occurrence of process innovation.

- The other independent variables are interpreted by focusing on the PCRE1 and PCRI1 models. Because these models cover *total R&D expenditures*. The other independent variables except the *number of highly educated R&D personnel* are statistically significant and have positive effects on the likelihood of occurrence of process innovation in PCRE1 and PCRI1 models. It means that more R&D intensity, more *turnover*, more concentrated Turkish manufacturing industry, and more *industrial production index by manufacturing industry* increase the likelihood of occurrence of process innovation in Turkish manufacturing industry.

Results of the analyses are also viewed by comparing product and process innovation in terms of section C. The analysis of Turkish manufacturing industry as a whole (by section C) provides many results such as:

- The impact of *total R&D expenditure* on the likelihood of occurrence of process innovation is greater than its impact on the likelihood of occurrence of product innovation.
- The impacts of *internal* and *external R&D expenditures* on the likelihood of occurrence of product innovation are greater than its impact on the likelihood of occurrence of process innovation.
- *External-domestic R&D expenditure* affects only the likelihood of occurrence of product innovation positively.
- *External-foreign R&D expenditure* affects only the likelihood of occurrence of process innovation positively.
- *Total R&D intensity* affects only the likelihood of occurrence of product innovation positively.

- The impact of *external*, *external-domestic*, and *external-foreign R&D intensity* on the likelihood of occurrence of process innovation is greater than its impact on the likelihood of occurrence of product innovation.

4.2.2. Turkish Manufacturing Industry Analysis by Division

The analysis of Turkish manufacturing industry by NACE Rev. 2 2-digit (by division) include the analysis of twelve divisions such as 10-manufacture of food products, 13-manufacture of textiles, 20-manufacture of chemicals and chemical products, 21-manufacture of basic pharmaceutical products and pharmaceutical preparations, 22-manufacture of rubber and plastic products, 23-manufacture of other non-metallic mineral products, 24-manufacture of basic metals, 25-manufacture of fabricated metal products, except machinery and equipment, 26-manufacture of computer, electronic and optical products 27-manufacture of electrical equipment, 28-manufacture of machinery and equipment n.e.c., and 29-manufacture of motor vehicles, trailers and semi-trailers.

The rest of divisions could not be analyzed here because there are not enough number of firm (clusters/groups). According to Mancl and DeRouen (2001), robust variance estimator produces valid standard errors even if correlation structure of the population-averaged panel data model is not correct structure, in order to do that, number of clusters/groups must be at least 40. That is why only twelve division in Turkish manufacturing industry are analyzed.

4.2.2.1. Manufacture of Food Products, C-10 by NACE Rev. 2

Firms that are engaged in R&D in manufacture of food products are analyzed with twenty models such as 10 product innovation models and 10 process innovation models.

Regression results of PDRE1 and PCRE1 models include coefficient, p-value, and average marginal effect, which are shown in Table 36. These models analyze the effect of *total R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE1 model focuses on the relationship between product innovation and *total R&D expenditure*, which is shown in Table 36. In this model, independent variables are not statistically significant at 10% level, except *HHI*. Hence, the null hypothesis, $H1_0$, is not rejected. *HHI* is statistically significant at 5% level. It means, *ceteris paribus*, that an increase in *HHI* of 0.01, on average, leads to an increase of 199.5 in the likelihood of occurrence of process innovation.

Table 36: Regression Results of PDRE1 and PCRE1 Models – C-10

Variable Name	PDRE1			PCRE1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>lntrdexpD</i>	0.0751	0.218	0.0246			
<i>rdperint</i>	0.2800	0.889	0.0917			
<i>lntoverD</i>	0.1448	0.140	0.0474			
<i>HHI</i>	608.9419	0.010 **	199.5028			
<i>phd_ma</i>	-0.0129	0.456	-0.0042			
<i>ipicsec</i>	0.0102	0.277	0.0033			

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE1: Wald $\chi^2(6) = 21.15$ Prob > $\chi^2 = 0.0017$

For PCRE1: Wald $\chi^2(6) = 7.75$ Prob > $\chi^2 = 0.2567$

The PCRE1 model focuses on the relationship between process innovation and *total R&D expenditure*, which is shown in Table 36. Because the Wald test and 5 of 6 individual z-statistics (not shown here) are not statistically significant, the PCRE1 model is not shown here. Hence, the null hypothesis, $H3_0$, could not be tested for manufacture of food products.

Regression results of PDRE2 and PCRE2 models include coefficient, p-value, and average marginal effect, which are shown in Table 37. These models analyze the effect of *internal R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE2 model focuses on the relationship between product innovation and *internal R&D expenditure*, which is shown in Table 37. In this model, independent variables are not statistically significant at 10% level, except *HHI*. Hence, the null hypothesis, $H1a_0$, is not rejected. *HHI* is statistically significant at 1% level. It means, *ceteris paribus*, that an increase in *HHI* of 0.01, on average, leads to an increase of 200.93 in the likelihood of occurrence of product innovation.

The PCRE2 model focuses on the relationship between process innovation and *internal R&D expenditure*, which is shown in Table 37. Because the Wald test and 5 of 6 individual z-statistics (not shown here) are not statistically significant, the PCRE2 model is not shown here. Hence, the null hypothesis, $H3a_0$, could not be tested for manufacture of food products.

Table 37: Regression Results of PDRE2 and PCRE2 Models – C-10

Variable Name	PDRE2			PCRE2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntintrdexpD</i>	0.0743	0.250	0.0243			
<i>rdperint</i>	0.2736	0.893	0.0897			
<i>IntoverD</i>	0.1461	0.139	0.0479			
<i>HHI</i>	613.1998	0.009 ***	200.9258			
<i>phd_ma</i>	-0.0130	0.449	-0.0043			
<i>ipicsec</i>	0.0104	0.268	0.0034			

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE2: Wald $\chi^2(6) = 21.19$ Prob > $\chi^2 = 0.0017$

For PCRE2: Wald $\chi^2(6) = 8.19$ Prob > $\chi^2 = 0.2242$

Regression results of PDRE3 and PCRE3 models include coefficient, p-value, and average marginal effect, which are shown in Table 38. These models analyze the effect of *external R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE3 model focuses on the relationship between product innovation and *external R&D expenditure*, which is shown in Table 38. In this model, independent variables are not statistically significant at 10% level, except *HHI* and *turnover*. Hence, the null hypothesis, $H1b_0$, is not rejected. *HHI* is statistically significant at 5% level. *Turnover* is statistically significant at 10% level. There are many results of this model, *ceteris paribus*, such as:

- An increase in *HHI* of 0.01, on average, leads to an increase of 195.53 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.9 percent in the likelihood of occurrence of product innovation.

The PCRE3 model focuses on the relationship between process innovation and *external R&D expenditure*, which is shown in Table 38. In this model, independent

variables are not statistically significant at 10% level, except *turnover*. Hence, the null hypothesis, $H3b_0$, is not rejected. According to this model, a 1 percent increase in the value of *turnover*, on average, leads to an increase of 6.88 percent in the likelihood of occurrence of process innovation.

Table 38: Regression Results of PDRE3 and PCRE3 Models – C-10

Variable Name	PDRE3			PCRE3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntexrdexpD</i>	0.0179	0.184	0.0059	-0.0198	0.146	-0.0057
<i>rdperint</i>	1.0674	0.577	0.3528	1.1383	0.558	0.3243
<i>IntoverD</i>	0.1784	0.054 *	0.0590	0.2416	0.011 **	0.0688
<i>HHI</i>	591.5837	0.012 **	195.5284	183.2655	0.644	52.2171
<i>phd_ma</i>	-0.0067	0.689	-0.0022	-0.0087	0.704	-0.0025
<i>ipicsec</i>	0.0105	0.261	0.0035	0.0096	0.472	0.0027

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE3: Wald $\chi^2(6) = 18.33$ Prob > $\chi^2 = 0.0055$

For PCRE3: Wald $\chi^2(6) = 11.44$ Prob > $\chi^2 = 0.0758$

Regression results of PDRE4 and PCRE4 models include coefficient, p-value, and average marginal effect, which are shown in Table 39. These models analyze the effect of *external-domestic R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE4 model focuses on the relationship between product innovation and *external-domestic R&D expenditure*, which is shown in Table 39. In this model, independent variables are not statistically significant at 10% level, except *turnover* and *HHI*. Hence, the null hypothesis, $H1c_0$, is not rejected. *Turnover* and *HHI* are statistically significant at 5% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 6.02 percent in the likelihood of occurrence of product innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 195.43 in the likelihood of occurrence of product innovation.

The PCRE4 model focuses on the relationship between process innovation and *external-domestic R&D expenditure*, which is shown in Table 39. In this model, independent variables are not statistically significant at 10% level, except *turnover*.

Hence, the null hypothesis, $H3c_0$, is not rejected. According to the model, a 1 percent increase in the value of *turnover*, on average, leads to an increase of 6.85 percent in the likelihood of occurrence of product innovation.

Table 39: Regression Results of PDRE4 and PCRE4 Models – C-10

Variable Name	PDRE4			PCRE4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpdomD</i>	0.0133	0.380	0.0044	-0.0240	0.109	-0.0068
<i>rdperint</i>	1.2258	0.529	0.4056	0.9190	0.651	0.2613
<i>IntoverD</i>	0.1820	0.049 **	0.0602	0.2411	0.011 **	0.0685
<i>HHI</i>	590.5806	0.012 **	195.4338	190.4466	0.631	54.1384
<i>phd_ma</i>	-0.0074	0.660	-0.0025	-0.0086	0.709	-0.0024
<i>ipicsec</i>	0.0104	0.261	0.0035	0.0100	0.457	0.0028

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE4: Wald $\chi^2(6)=18.42$ Prob > $\chi^2=0.0053$

For PCRE4: Wald $\chi^2(6)=11.97$ Prob > $\chi^2=0.0625$

Regression results of PDRE5 and PCRE5 models include coefficient, p-value, and average marginal effect, which are shown in Table 40. These models analyze the effect of *external-foreign R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE5 model focuses on the relationship between product innovation and *external-foreign R&D expenditure*, which is shown in Table 40. In this model, independent variables are not statistically significant at 10% level, except *turnover* and *HHI*. Hence, the null hypothesis, $H1d_0$, is not rejected. *Turnover* and *HHI* are statistically significant at 5% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 6.09 percent in the likelihood of occurrence of product innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 199.43 in the likelihood of occurrence of product innovation.

The PCRE5 model focuses on the relationship between process innovation and *external-foreign R&D expenditure*, which is shown in Table 40. Because the Wald test and 5 of 6 individual z-statistics (not shown here) are not statistically significant, the PCRE5 model is not shown here. In other words, the model is not statistically

significant. Hence, the null hypothesis, $H3d_0$, could not be tested for manufacture of food products.

Table 40: Regression Results of PDRE5 and PCRE5 Models – C-10

Variable Name	PDRE5			PCRE5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpforD</i>	0.0110	0.449	0.0036			
<i>rdperint</i>	1.1393	0.558	0.3769			
<i>IntoverD</i>	0.1842	0.047 **	0.0609			
<i>HHI</i>	602.8247	0.011 **	199.4320			
<i>phd_ma</i>	-0.0078	0.649	-0.0026			
<i>ipicsec</i>	0.0109	0.245	0.0036			

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE5: Wald $\chi^2(6) = 18.77$ Prob > $\chi^2 = 0.0046$

For PCRE5: Wald $\chi^2(6) = 7.18$ Prob > $\chi^2 = 0.3044$

Regression results of PDRI1 and PCRI1 models include coefficient, p-value, and average marginal effect, which are shown in Table 41. These models analyze the effect of *total R&D intensity* on the probability of product and process innovations, respectively.

The PDRI1 model focuses on the relationship between product innovation and *total R&D intensity*, which is shown in Table 41. In this model, independent variables are not statistically significant at 10% level, except *turnover* and *HHI*. Hence, the null hypothesis, $H2_0$, is rejected. *Turnover* and *HHI* are statistically significant at 5% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 6.16 percent in the likelihood of occurrence of product innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 197.9 in the likelihood of occurrence of product innovation.

The PCRI1 model focuses on the relationship between process innovation and *total R&D intensity*, which is shown in Table 41. Because the Wald test and 5 of 6 individual z-statistics (not shown here) are not statistically significant, the PCRI1 model is not shown here. In other words, the model is not statistically significant. Hence, the null hypothesis, $H4_0$, could not be tested for manufacture of food products.

Table 41: Regression Results of PDRI1 and PCRI1 Models – C-10

Variable Name	PDRI1			PCRI1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>totrdint</i>	-0.0700	0.971	-0.0232			
<i>rdperint</i>	1.2660	0.521	0.4189			
<i>IntoverD</i>	0.1861	0.049 **	0.0616			
<i>HHI</i>	598.1622	0.010 **	197.90			
<i>phd_ma</i>	-0.0082	0.630	-0.0027			
<i>ipicsec</i>	0.0108	0.248	0.0036			

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI1: Wald chi2(6)=18.66 Prob > chi2=0.0048

For PCRI1: Wald chi2(6)=10.26 Prob > chi2=0.1142

Regression results of PDRI2 and PCRI2 models include coefficient, p-value, and average marginal effect, which are shown in Table 42. These models analyze the effect of *internal R&D intensity* on the probability of product and process innovations, respectively.

The PDRI2 model focuses on the relationship between product innovation and *internal R&D intensity*, which is shown in Table 42. In this model, independent variables are not statistically significant at 10% level, except *turnover* and *HHI*. Hence, the null hypothesis, $H2a_0$, is not rejected. *Turnover* is statistically significant at 10% level. *HHI* is statistically significant at 5% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 6.11 percent in the likelihood of occurrence of product innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 197.56 in the likelihood of occurrence of product innovation.

The PCRI2 model focuses on the relationship between process innovation and *internal R&D intensity*, which is shown in Table 42. Because the Wald test and 5 of 6 individual z-statistics (not shown here) are not statistically significant, the PCRI2 model is not shown here. In other words, the model is not statistically significant. Hence, the null hypothesis, $H4a_0$, could not be tested for manufacture of food products.

Table 42: Regression Results of PDRI2 and PCRI2 Models – C-10

Variable Name	PDRI2			PCRI2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>intrdint</i>	-0.2838	0.932	-0.0939			
<i>rdperint</i>	1.3021	0.520	0.4309			
<i>IntoverD</i>	0.1848	0.059 *	0.0611			
<i>HHI</i>	597.0550	0.010 **	197.56			
<i>phd_ma</i>	-0.0081	0.637	-0.0027			
<i>ipicsec</i>	0.0107	0.248	0.0036			

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI2: Wald $\chi^2(6) = 18.70$ Prob $> \chi^2 = 0.0047$

For PCRI2: Wald $\chi^2(6) = 7.59$ Prob $> \chi^2 = 0.2699$

Regression results of PDRI3 and PCRI3 models include coefficient, p-value, and average marginal effect, which are shown in Table 43. These models analyze the effect of *external R&D intensity* on the probability of product and process innovations, respectively.

The PDRI3 model focuses on the relationship between product innovation and *external R&D intensity*, which is shown in Table 43. In this model, independent variables are not statistically significant at 10% level, except *turnover* and *HHI*. Hence, the null hypothesis, $H2b_0$, is not rejected. *Turnover* is statistically significant at 10% level. *HHI* is statistically significant at 5% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 6.16 percent in the likelihood of occurrence of product innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 197.74 in the likelihood of occurrence of product innovation.

The PCRI3 model focuses on the relationship between process innovation and *external R&D intensity*, which is shown in Table 43. Because the Wald test and 5 of 6 individual z-statistics (not shown here) are not statistically significant, the PCRI3 model is not shown here. In other words, the model is not statistically significant. Hence, the null hypothesis, $H4b_0$, could not be tested for manufacture of food products.

Table 43: Regression Results of PDRI3 and PCRI3 Models – C-10

Variable Name	PDRI3			PCRI3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extrdint</i>	0.2980	0.614	0.0986			
<i>rdperint</i>	1.2526	0.521	0.4144			
<i>IntoverD</i>	0.1864	0.044 **	0.0616			
<i>HHI</i>	597.7261	0.011 **	197.74			
<i>phd_ma</i>	-0.0082	0.631	-0.0027			
<i>ipicsec</i>	0.0107	0.251	0.0036			

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI3: Wald $\chi^2(6) = 19.22$ Prob > $\chi^2 = 0.0038$

For PCRI3: Wald $\chi^2(6) = 7.25$ Prob > $\chi^2 = 0.2979$

Regression results of PDRI4 and PCRI4 models include coefficient, p-value, and average marginal effect, which are shown in Table 44. These models analyze the effect of *external-domestic R&D intensity* on the probability of product and process innovations, respectively.

The PDRI4 model focuses on the relationship between product innovation and *external-domestic R&D intensity*, which is shown in Table 44. In this model, independent variables are not statistically significant at 10% level, except *turnover* and *HHI*. Hence the null hypothesis, $H2c_0$, is not rejected. *Turnover* is statistically significant at 5% level. *HHI* is statistically significant at 1% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 6.15 percent in the likelihood of occurrence of product innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 202.2 in the likelihood of occurrence of product innovation.

The PCRI4 model focuses on the relationship between process innovation and *external-domestic R&D intensity*, which is shown in Table 44. In this model, independent variables are not statistically significant at 10% level, except *external-domestic R&D intensity* and *turnover*. Hence, the null hypothesis, $H4c_0$, is rejected. *External-domestic R&D intensity* is statistically significant at 1% level. *Turnover* is statistically significant at 5% level. There are many results of this model, *ceteris paribus*, such as:

- A unit decrease in the value of *external-domestic R&D intensity*, on average, leads to a decrease of 56.19 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 6.51 percent in the likelihood of occurrence of process innovation.

Table 44: Regression Results of PDRI4 and PCRI4 Models – C-10

Variable Name	PDRI4			PCRI4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extdomrdint</i>	-63.102	0.524	32.5758	-200.300	0.007 ***	-56.19
<i>rdperint</i>	1.1373	0.569	0.3745	0.4983	0.807	0.1398
<i>IntoverD</i>	0.1869	0.043 **	0.0615	0.2322	0.015 **	0.0651
<i>HHI</i>	613.962	0.009 ***	202.20	221.221	0.583	62.058
<i>phd_ma</i>	-0.0085	0.622	-0.0028	-0.0077	0.737	-0.0022
<i>ipicsec</i>	0.0113	0.234	0.0037	0.0111	0.419	0.0031

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI4: Wald chi2(6)=21.06 Prob > chi2=0.0018

For PCRI4: Wald chi2(6)=14.33 Prob > chi2=0.0261

Regression results of PDRI5 and PCRI5 models include coefficient, p-value, and average marginal effect, which are shown in Table 45. These models analyze the effect of *external-foreign R&D intensity* on the probability of product and process innovations, respectively.

The PDRI5 model focuses on the relationship between product innovation and *external-foreign R&D intensity*, which is shown in Table 45. In this model, independent variables such as *external-foreign R&D intensity*, *turnover*, and *HHI* are statistically significant at 5% level. Hence, the null hypothesis, H_{2d_0} , is rejected. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external-foreign R&D intensity*, on average, leads to an increase of 144.24 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 6.10 percent in the likelihood of occurrence of product innovation.

- An increase in *HHI* of 0.01, on average, leads to an increase of 201.15 in the likelihood of occurrence of product innovation.

Table 45: Regression Results of PDRI5 and PCRI5 Models – C-10

Variable Name	PDRI5			PCRI5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extfrgrdint</i>	439.570	0.049 **	144.24	0.6477	0.226	0.1859
<i>rdperint</i>	0.7811	0.694	0.2563	0.8034	0.685	0.2306
<i>IntoverD</i>	0.1858	0.045 **	0.0610	0.2280	0.017 **	0.0654
<i>HHI</i>	612.997	0.010 **	201.15	181.364	0.645	52.0459
<i>phd_ma</i>	-0.0079	0.646	-0.0026	-0.0064	0.776	-0.0018
<i>ipicsec</i>	0.0112	0.237	0.0037	0.0093	0.484	0.0027

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI5: Wald chi2(6)=22.37 Prob > chi2=0.0010

For PCRI5: Wald chi2(6)=284.65 Prob > chi2=0.0000

The PCRI5 model focuses on the relationship between process innovation and *external-foreign R&D intensity*, which is shown in Table 45. In this model, independent variables are not statistically significant at the 10% level, except *turnover*. Hence, the null hypothesis, $H4d_0$, is not rejected. *Turnover* is statistically significant at the 5% level. According to the model, a 1 percent increase in the value of *turnover*, on average, leads to an increase of 6.54 percent in the likelihood of occurrence of process innovation.

According to the analysis of the manufacture of food products, there are many findings in terms of product innovation. These are:

- R&D expenditure variables are not statistically significant at 10% level in terms of the likelihood of occurrence of product innovation in Turkish manufacturing industry.
- R&D intensity variables except *external-foreign R&D intensity* (PDRI5 model) are not statistically significant at 10% level in terms of the likelihood of occurrence of product innovation in Turkish manufacturing industry. The effect of *external-foreign R&D intensity* on the likelihood of occurrence of product innovation is positive.
- The other independent variables are interpreted by focusing on the PDRE1 and PDRI1 models. Because these models cover *total R&D expenditures*.

According to the PDRE1 model, *HHI* is statistically significant and has positive effect on the likelihood of occurrence of product innovation. According to the PDRI1 model, *turnover* and *HHI* are statistically significant and has positive effect on the likelihood of occurrence of product innovation. It means that more concentrated food products market and more *turnover* increases the likelihood of occurrence of product innovation in the manufacture of food products.

According to the analysis of the manufacture of food products, there are many findings in terms of process innovation. These are:

- R&D expenditure variables are not statistically significant and PCRE1, PCRE2 and PCRE5 models are not statistically significant according to the Wald test.
- R&D intensity variables except external-domestic are not statistically significant at 10% level, and PCRI1, PCRI2, and PCRI3 models are not statistically significant according to the Wald test. However, *external-domestic R&D intensity* has negative effect on the likelihood of occurrence of process innovation in the manufacture of food products. This result does not meet the hypothesis.
- The other independent variables are interpreted by focusing on the PCRE1 and PCRI1 models. Because these models cover *total R&D expenditures*. PCRE1 and PCRI1 models are not statistically significant according to the Wald test.

Results of the analyses are also viewed by comparing product and process innovation in terms of the manufacture of food products. These are:

- *External-domestic R&D intensity* affects the likelihood of occurrence of process innovation negatively instead of the likelihood of occurrence of product innovation.

- *External-foreign R&D intensity* affects the likelihood of occurrence of product innovation positively instead of the likelihood of occurrence of process innovation.

4.2.2.2. Manufacture of Textiles, C-13 by NACE Rev. 2

Firms that are engaged in R&D in manufacture of textiles are analyzed with twenty models such as 10 product innovation models and 10 process innovation models.

Regression results of PDRE1 and PCRE1 models include coefficient, p-value, and average marginal effect, which are shown in Table 46. These models analyze the effect of *total R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE1 model focuses on the relationship between product innovation and *total R&D expenditure*, which is shown in Table 46. In this model, independent variables are not statistically significant at 10% level, except *total R&D expenditure*. It is statistically significant at 5% level. Hence, the null hypothesis, $H1_0$, is rejected. It means that a 1 percent increase in the value of *total R&D expenditure*, on average, leads to an increase of 4.62 percent in the likelihood of occurrence of product innovation.

The PCRE1 model focuses on the relationship between process innovation and *total R&D expenditure*, which is shown in Table 46. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity* and *turnover*. Hence, the null hypothesis, $H3_0$, is not rejected. *R&D personnel intensity* is statistically significant at 10% level. *Turnover* is statistically significant at the 1% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 19.25 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 3.32 in the likelihood of occurrence of process innovation.

Table 46: Regression Results of PDRE1 and PCRE1 Models – C-13

Variable Name	PDRE1			PCRE1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntrdexpD</i>	0.1409	0.035 **	0.0462	-0.0954	0.316	-0.0258
<i>rdperint</i>	2.7155	0.295	0.8896	12.2787	0.056 *	3.3240
<i>IntoverD</i>	0.1800	0.145	0.0590	0.7111	0.000 ***	0.1925
<i>HHI</i>	-332.64	0.759	-108.97	-1362.19	0.344	-368.76
<i>phd_ma</i>	-0.0063	0.686	-0.0021	0.0006	0.975	0.0002
<i>ipicsec</i>	-0.0012	0.875	-0.0004	0.0010	0.902	0.0003

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE1: Wald chi2(6)=17.79 Prob > chi2=0.0068

For PCRE1: Wald chi2(6)=24.14 Prob > chi2=0.0005

Regression results of PDRE2 and PCRE2 models include coefficient, p-value, and average marginal effect, which are shown in Table 47. These models analyze the effect of *internal R&D expenditure* on the probability of product and process innovations, respectively.

Table 47: Regression Results of PDRE2 and PCRE2 Models – C-13

Variable Name	PDRE2			PCRE2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntintrdexpD</i>	0.1382	0.043 **	0.0453	-0.0967	0.309	-0.0262
<i>rdperint</i>	2.7405	0.296	0.8984	12.3119	0.055 *	3.3331
<i>IntoverD</i>	0.1819	0.144	0.0596	0.7120	0.000 ***	0.1927
<i>HHI</i>	-321.454	0.767	-105.379	-1370.569	0.341	-371.045
<i>phd_ma</i>	-0.0060	0.699	-0.0020	0.0007	0.972	0.0002
<i>ipicsec</i>	-0.0012	0.881	-0.0004	0.0010	0.906	0.0003

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE2: Wald chi2(6)=17.57 Prob > chi2=0.0074

For PCRE2: Wald chi2(6)=24.15 Prob > chi2=0.0005

The PDRE2 model focuses on the relationship between product innovation and *internal R&D expenditure*, which is shown in Table 47. In this model, independent variables are not statistically significant at 10% level, except *internal R&D expenditure*. It is statistically significant at 5% level. Hence, the null hypothesis, $H1a_0$, is rejected. It means that a 1 percent increase in the value of *total R&D expenditure*, on average, leads to an increase of 4.53 percent in the likelihood of occurrence of product innovation.

The PCRE2 model focuses on the relationship between process innovation and *internal R&D expenditure*, which is shown in Table 47. In this model, independent

variables are not statistically significant at 10% level, except *R&D personnel intensity* and *turnover*. Hence, the null hypothesis, $H3a_0$, is not rejected. *R&D personnel intensity* is statistically significant at 10% level. *Turnover* is statistically significant at the 1% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 19.27 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 3.33 in the likelihood of occurrence of process innovation.

Regression results of PDRE3 and PCRE3 models include coefficient, p-value, and average marginal effect, which are shown in Table 48. These models analyze the effect of *external R&D expenditure* on the probability of product and process innovations, respectively.

Table 48: Regression Results of PDRE3 and PCRE3 Models – C-13

Variable Name	PDRE3			PCRE3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpD</i>				0.0010	0.960	0.0003
<i>rdperint</i>				10.2550	0.047 **	2.7514
<i>IntoverD</i>				0.6356	0.000 ***	0.1705
<i>HHI</i>				-1334.48	0.376	-358.037
<i>phd_ma</i>				-0.0067	0.727	-0.0018
<i>ipicsec</i>				0.0007	0.933	0.0002

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE3: Wald $\chi^2(6) = 9.51$ Prob > $\chi^2 = 0.1468$

For PCRE3: Wald $\chi^2(6) = 25.99$ Prob > $\chi^2 = 0.0002$

The PDRE3 model focuses on the relationship between product innovation and *external R&D expenditure*, which is shown in Table 48. Because the Wald test and 4 of 6 individual z-statistics (not shown here) are not statistically significant, the PDRE3 model is not shown here. Hence, the null hypothesis, $H1b_0$, could not be tested for manufacture of textiles.

The PCRE3 model focuses on the relationship between process innovation and *external R&D expenditure*, which is shown in Table 48. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity* and *turnover*. Hence, the null hypothesis, $H3b_0$, is not rejected. *R&D personnel*

intensity is statistically significant at 5% level. *Turnover* is statistically significant at the 1% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 17.05 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 2.75 in the likelihood of occurrence of process innovation.

Regression results of PDRE4 and PCRE4 models include coefficient, p-value, and average marginal effect, which are shown in Table 49. These models analyze the effect of *external-domestic R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE4 model focuses on the relationship between product innovation and *external-domestic R&D expenditure*, which is shown in Table 49. Because the Wald test and 4 of 6 individual z-statistics (not shown here) are not statistically significant, the PDRE4 model is not shown here. Hence, the null hypothesis, $H1c_0$, could not be tested for manufacture of textiles.

Table 49: Regression Results of PDRE4 and PCRE4 Models – C-13

Variable Name	PDRE4			PCRE4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpdomD</i>				-0.0117	0.545	-0.0031
<i>rdperint</i>				10.3566	0.048 **	2.7826
<i>IntoverD</i>				0.6440	0.000 ***	0.1730
<i>HHI</i>				-1234.663	0.409	-331.734
<i>phd_ma</i>				-0.0072	0.706	-0.0019
<i>ipicsec</i>				0.0011	0.894	0.0003

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE4: Wald chi2(6)=9.49 Prob > chi2=0.1477

For PCRE4: Wald chi2(6)=24.91 Prob > chi2=0.0004

The PCRE4 model focuses on the relationship between process innovation and *external-domestic R&D expenditure*, which is shown in Table 49. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity* and *turnover*. Hence, the null hypothesis, $H3c_0$, is not rejected. *R&D personnel intensity* is statistically significant at 5% level. *Turnover* is statistically significant at 1% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 17.30 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 2.78 in the likelihood of occurrence of process innovation.

Regression results of PDRE5 and PCRE5 models include coefficient, p-value, and average marginal effect, which are shown in Table 50. These models analyze the effect of *external-foreign R&D expenditure* on the probability of product and process innovations, respectively.

Table 50: Regression Results of PDRE5 and PCRE5 Models – C-13

Variable Name	PDRE5			PCRE5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpforD</i>				0.0263	0.303	0.0070
<i>rdperint</i>				10.1340	0.045 **	2.7112
<i>IntoverD</i>				0.6268	0.000 ***	0.1677
<i>HHI</i>				-1378.302	0.360	-368.746
<i>phd_ma</i>				-0.0089	0.622	-0.0024
<i>ipicsec</i>				0.0007	0.931	0.0002

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE5: Wald chi2(6)=9.98 Prob > chi2=0.1256

For PCRE5: Wald chi2(6)=28.32 Prob > chi2=0.0001

The PDRE5 model focuses on the relationship between product innovation and *external-foreign R&D expenditure*, which is shown in Table 50. Because the Wald test and 4 of 6 individual z-statistics (not shown here) are not statistically significant, the PDRE5 model is not shown here. Hence, the null hypothesis, $H1d_0$, could not be tested for manufacture of textiles.

The PCRE5 model focuses on the relationship between process innovation and *external-foreign R&D expenditure*, which is shown in Table 50. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity* and *turnover*. Hence, the null hypothesis, $H3d_0$, is not rejected. *R&D personnel intensity* is statistically significant at 5% level. *Turnover* is statistically significant at 1% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 16.77 percent in the likelihood of occurrence of process innovation.

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 2.71 in the likelihood of occurrence of process innovation.

Regression results of PDRI1 and PCRI1 models include coefficient, p-value, and average marginal effect, which are shown in Table 51. These models analyze the effect of *total R&D intensity* on the probability of product and process innovations, respectively.

Table 51: Regression Results of PDRI1 and PCRI1 Models – C-13

Variable Name	PDRI1			PCRI1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>totrdint</i>	15.0848	0.003 ***	4.8602	-5.6391	0.565	-1.5181
<i>rdperint</i>	2.4970	0.260	0.8045	11.5649	0.067 *	3.1134
<i>IntoverD</i>	0.3679	0.002 ***	0.1185	0.6241	0.000 ***	0.1680
<i>HHI</i>	-464.627	0.675	-149.698	-1351.82	0.358	-363.93
<i>phd_ma</i>	-0.0054	0.732	-0.0017	-0.0036	0.857	-0.0010
<i>ipicsec</i>	-0.0019	0.812	-0.0006	0.0009	0.919	0.0002

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI1: Wald chi2(6)=19.17 Prob > chi2=0.0039

For PCRI1: Wald chi2(6)=23.01 Prob > chi2=0.0008

The PDRI1 model focuses on the relationship between product innovation and *total R&D intensity*, which is shown in Table 51. In this model, *total R&D intensity* and *turnover* are statistically significant at 1% level and the rest of them is not statistically significant at 10% level. Hence, the null hypothesis, H_{20} , is rejected. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *total R&D intensity*, on average, leads to an increase of 4.86 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 11.85 percent in the likelihood of occurrence of product innovation.

The PCRI1 model focuses on the relationship between process innovation and *total R&D intensity*, which is shown in Table 51. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity* and *turnover*. Hence, the null hypothesis, H_{40} , is not rejected. *R&D personnel intensity* is statistically significant at 10% level. *Turnover* is statistically significant at 1% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 16.80 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 3.11 in the likelihood of occurrence of process innovation.

Regression results of PDRI2 and PCRI2 models include coefficient, p-value, and average marginal effect, , which are shown in Table 52. These models analyze the effect of *internal R&D intensity* on the probability of product and process innovations, respectively.

Table 52: Regression Results of PDRI2 and PCRI2 Models – C-13

Variable Name	PDRI2			PCRI2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>intrdint</i>	14.5441	0.003 ***	4.6918	-5.933	0.566	-1.5973
<i>rdperint</i>	2.5646	0.251	0.8273	11.628	0.068 *	3.1306
<i>lntoverD</i>	0.3665	0.002 ***	0.1182	0.624	0.000 ***	0.1680
<i>HHI</i>	-463.902	0.676	-149.65	-1354.38	0.357	-364.649
<i>phd_ma</i>	-0.0050	0.753	-0.0016	-0.003	0.862	-0.0009
<i>ipicsec</i>	-0.0019	0.814	-0.0006	0.001	0.920	0.0002

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI2: Wald chi2(6)=18.84 Prob > chi2=0.0044

For PCRI2: Wald chi2(6)=22.95 Prob > chi2=0.0008

The PDRI2 model focuses on the relationship between product innovation and *internal R&D intensity*, which is shown in Table 52. In this model, independent variables are not statistically significant at the 10% level, except *internal R&D intensity* and *turnover*. Hence, the null hypothesis, $H2a_0$, is rejected. *R&D personnel intensity* and *turnover* are statistically significant at the 1% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *internal R&D intensity*, on average, leads to an increase of 4.70 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 11.82 percent in the likelihood of occurrence of product innovation.

The PCRI2 model focuses on the relationship between process innovation and *internal R&D intensity*, which is shown in Table 52. In this model, independent

variables are not statistically significant at 10% level, except *R&D personnel intensity* and *turnover*. Hence, the null hypothesis, $H4a_0$, is not rejected. *R&D personnel intensity* is statistically significant at 10% level. *Turnover* is statistically significant at 1% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 16.80 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 3.13 in the likelihood of occurrence of process innovation.

Regression results of PDRI3 and PCRI3 models include coefficient, p-value, and average marginal effect, which are shown in Table 53. These models analyze the effect of *external R&D intensity* on the probability of product and process innovations, respectively.

The PDRI3 model focuses on the relationship between product innovation and *external R&D intensity*, which is shown in Table 53. In this model, independent variables are not statistically significant at the 10% level, except *external R&D intensity*, *R&D personnel intensity*, and *turnover*. *External R&D intensity* is significant at the 1% level. Hence, the null hypothesis, $H2b_0$, is rejected. *R&D personnel intensity* and *turnover* are statistically significant at the 10% and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external R&D intensity*, on average, leads to an increase of 103.59 in the likelihood of occurrence of product innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 1.58 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 8.8 percent in the likelihood of occurrence of product innovation.

The PCRI3 model focuses on the relationship between process innovation and *external R&D intensity*, which is shown in Table 53. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity* and *turnover*. Hence, the null hypothesis, $H4b_0$, is not rejected. *R&D personnel*

intensity is statistically significant at 5% level. *Turnover* is statistically significant at the 1% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 17.05 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 2.75 in the likelihood of occurrence of process innovation.

Table 53: Regression Results of PDRI3 and PCRI3 Models – C-13

Variable Name	PDRI3			PCRI3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extrdint</i>	310.133	0.008 ***	103.586	68.0623	0.731	18.2656
<i>rdperint</i>	4.7339	0.065 *	1.5811	10.2354	0.045 **	2.7468
<i>IntoverD</i>	0.2634	0.020 **	0.0880	0.6352	0.000 ***	0.1705
<i>HHI</i>	-443.255	0.678	-148.050	-1337.10	0.371	-358.831
<i>phd_ma</i>	0.0014	0.922	0.0005	-0.0073	0.694	-0.0020
<i>ipicsec</i>	-0.0011	0.881	-0.0004	0.0006	0.944	0.0002

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI3: Wald chi2(6)=14.68 Prob > chi2=0.0229

For PCRI3: Wald chi2(6)=25.45 Prob > chi2=0.0003

Regression results of PDRI4 and PCRI4 models include coefficient, p-value, and average marginal effect, which are shown in Table 54. These models analyze the effect of *external-domestic R&D intensity* on the probability of product and process innovations, respectively.

The PDRI4 model focuses on the relationship between product innovation and *external-domestic R&D intensity*, which is shown in Table 54. In this model, independent variables are not statistically significant at the 10% level, except *external-domestic R&D intensity*, *R&D personnel intensity*, and *turnover*. *External-domestic R&D intensity* is significant at the 5% level. Hence, the null hypothesis, H_{2c0} , is rejected. *R&D personnel intensity* and *turnover* are statistically significant at the 10% and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external-domestic R&D intensity*, on average, leads to an increase of 75.5 in the likelihood of occurrence of product innovation.

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 1.62 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 9.03 percent in the likelihood of occurrence of product innovation.

The PCRI4 model focuses on the relationship between process innovation and *external-domestic R&D intensity*, which is shown in Table 54. In this model, independent variables are not statistically significant at 10% level, except *external-domestic R&D intensity*, *R&D personnel intensity*, and *turnover*. *External-domestic R&D intensity* and *R&D personnel intensity* is statistically significant at 5% level. Hence, the null hypothesis, $H4c_0$, is rejected. *Turnover* is statistically significant at the 1% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external-domestic R&D intensity*, on average, leads to an increase of 40.14 in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 2.73 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 16.98 percent in the likelihood of occurrence of process innovation.

Table 54: Regression Results of PDRI4 and PCRI4 Models – C-13

Variable Name	PDRI4			PCRI4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extdomrdint</i>	224.776	0.010 **	75.4954	-348.150	0.026 **	40.136
<i>rdperint</i>	4.8289	0.066 *	1.6219	10.2168	0.048 **	2.7340
<i>lntoverD</i>	0.2689	0.018 **	0.0903	0.6345	0.000 ***	0.1698
<i>HHI</i>	-444.573	0.677	-149.319	-1249.452	0.404	-334.353
<i>phd_ma</i>	0.0023	0.881	0.0008	-0.0051	0.796	-0.0014
<i>ipicsec</i>	-0.0011	0.886	-0.0004	0.0014	0.875	0.0004

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI4: Wald chi2(6)=15.10 Prob > chi2=0.0195

For PCRI4: Wald chi2(6)=27.93 Prob > chi2=0.0001

Regression results of PDRI5 and PCRI5 models include coefficient, p-value, and average marginal effect, which are shown in Table 55. These models analyze the

effect of *external-foreign R&D intensity* on the probability of product and process innovations, respectively.

The PDRI5 model focuses on the relationship between product innovation and *external-foreign R&D intensity*, which is shown in Table 55. In this model, independent variables are not statistically significant at the 10% level, except *external-foreign R&D intensity*, *R&D personnel intensity*, and *turnover*. *External-foreign R&D intensity* is significant at the 1% level. Hence, the null hypothesis, $H2d_0$, is rejected. *R&D personnel intensity* and *turnover* are statistically significant at the 10% and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external-foreign R&D intensity*, on average, leads to an increase of 179.4 in the likelihood of occurrence of product innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 2.7 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 16.76 percent in the likelihood of occurrence of product innovation.

The PCRI5 model focuses on the relationship between process innovation and *external-foreign R&D intensity*, which is shown in Table 55. In this model, independent variables are not statistically significant at 10% level, except *external-foreign R&D intensity*, *R&D personnel intensity*, and *turnover*. *External-foreign R&D intensity* is statistically significant at 1% level. Hence, the null hypothesis, $H4d_0$, is rejected. *R&D personnel intensity* and *turnover* are statistically significant at the 10% and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external-foreign R&D intensity*, on average, leads to an increase of 179.4 in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 2.7 in the likelihood of occurrence of process innovation.

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 16.76 percent in the likelihood of occurrence of process innovation.

Table 55: Regression Results of PDRI5 and PCRI5 Models – C-13

Variable Name	PDRI5			PCRI5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extfrgrdint</i>	458.779	0.009 ***	153.52	667.877	0.078 *	179.40
<i>rdperint</i>	4.6621	0.071 *	1.5600	10.0515	0.043 **	2.7000
<i>IntoverD</i>	0.2610	0.021 **	0.0873	0.6241	0.000 ***	0.1676
<i>HHI</i>	-411.733	0.699	-137.77	-1330.94	0.374	-357.51
<i>phd_ma</i>	0.0021	0.889	0.0007	-0.0096	0.587	-0.0026
<i>ipicsec</i>	-0.0009	0.904	-0.0003	0.0007	0.935	0.0002

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI5: Wald chi2(6)=16.06 Prob > chi2=0.0134

For PCRI5: Wald chi2(6)=930.85 Prob > chi2=0.0000

According to the analysis of the manufacture of textiles, there are many findings in terms of product innovation. These are:

- R&D expenditure variables such as total and internal (PDRE1 and PDRE2 models, respectively) have positive effects on the likelihood of occurrence of product innovation in Turkish manufacturing industry. Both total and *internal R&D expenditures* have similar effects on the likelihood of occurrence of product innovation. For example, for both variables, a 1 percent increase in the value of total or *internal R&D expenditure*, on average, leads to an increase of approximately 4.53 percent in the likelihood of occurrence of product innovation.
- All R&D intensity variables (PDRI1, PDRI2, PDRI3, PDRI4, and PDRI5 models) have positive effects on the likelihood of occurrence of product innovation in Turkish manufacturing industry. The most effective R&D intensity variables are *external R&D expenditures*.
- The other independent variables are interpreted by focusing on the PDRE1 and PDRI1 models. Because these models cover *total R&D expenditures*. According to the PDRE1 model, these other independent variables are not statistically significant at 10% level. According to the PDRI1 model, *turnover* is statistically significant and has positive effect on the likelihood

of occurrence of product innovation. It means that more *turnover* increases the likelihood of occurrence of product innovation in the manufacture of textiles.

According to the analysis of the manufacture of textiles, there are many findings in terms of process innovation. These are:

- All R&D expenditure variables are not statistically significant at 10% level.
- R&D intensity variables such as external-domestic and external-foreign (PCRI4 and PCRI5 models, respectively) have positive effects on the likelihood of occurrence of process innovation. The most effective R&D intensity variable is *external-foreign R&D intensity*.
- The other independent variables are interpreted by focusing on the PCRE1 and PCRI1 models. Because these models cover *total R&D expenditures*. According to the PCRE1 and PCRI1 models, these other independent variables except *R&D personnel intensity* and *turnover* are not statistically significant at 10% level. *R&D personnel intensity* and *turnover* are statistically significant and has positive effect on the likelihood of occurrence of process innovation. It means that more *R&D personnel intensity* and more *turnover* increase the likelihood of occurrence of process innovation in the manufacture of textiles.

Results of the analyses are also viewed by comparing product and process innovation in terms of the manufacture of textiles. These are:

- *Total* and *internal R&D expenditures* affect only the likelihood of occurrence of product innovation positively.
- All R&D intensities affect the likelihood of occurrence of product innovation positively.
- The impact of *external-domestic R&D intensity* on the likelihood of occurrence of product innovation is greater than its impact on the likelihood of occurrence of process innovation.

- The impact of *external-foreign R&D intensity* on the likelihood of occurrence of process innovation is greater than its impact on the likelihood of occurrence of product innovation.

4.2.2.3. Manufacture of Chemicals and Chemical Products, C-20 by NACE Rev. 2

Firms that are engaged in R&D in manufacture of chemicals and chemical products are analyzed with twenty models such as 10 product innovation models and 10 process innovation models.

Regression results of PDRE1 and PCRE1 models include coefficient, p-value, and average marginal effect, which are shown in Table 56. These models analyze the effect of *total R&D expenditure* on the probability of product and process innovations, respectively.

Table 56: Regression Results of PDRE1 and PCRE1 Models – C-20

Variable Name	PDRE1			PCRE1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>lntrdexpD</i>	0.0805	0.357	0.0240	0.0270	0.714	0.0089
<i>rdperint</i>	1.0371	0.294	0.3095	1.8168	0.027 **	0.5966
<i>IntoverD</i>	-0.0604	0.561	-0.0180	0.2234	0.023 **	0.0734
<i>HHI</i>	-29.085	0.507	-8.6798	-38.126	0.181	-12.52
<i>phd_ma</i>	0.0645	0.013 **	0.0192	-0.0014	0.943	-0.0005
<i>ipicsec</i>	0.0051	0.560	0.0015	0.0029	0.709	0.0010

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE1: Wald chi2(6)=20.79 Prob > chi2=0.0020

For PCRE1: Wald chi2(6)=18.34 Prob > chi2=0.0054

The PDRE1 model focuses on the relationship between product innovation and *total R&D expenditure*, which is shown in Table 56. In this model, independent variables are not statistically significant at 10% level, except the *number of highly educated R&D personnel*. Hence, the null hypothesis, $H1_0$, is not rejected. The *number of highly educated R&D personnel* is statistically significant at 5% level. It means that a 1 percent increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 1.92 percent in the likelihood of occurrence of product innovation.

The PCRE1 model focuses on the relationship between process innovation and *total R&D expenditure*, which is shown in Table 56. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity* and *turnover*. Hence, the null hypothesis, H_{30} , is not rejected. *R&D personnel intensity* and *turnover* are statistically significant at the 5% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.6 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 7.34 percent in the likelihood of occurrence of process innovation.

Regression results of PDRE2 and PCRE2 models include coefficient, p-value, and average marginal effect, which are shown in Table 57. These models analyze the effect of *internal R&D expenditure* on the probability of product and process innovations, respectively.

Table 57: Regression Results of PDRE2 and PCRE2 Models – C-20

Variable Name	PDRE2			PCRE2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntintrdexpD</i>	0.1002	0.253	0.0298	0.0402	0.591	0.0132
<i>rdperint</i>	0.9002	0.359	0.2681	1.7391	0.035 **	0.5706
<i>IntoverD</i>	-0.0763	0.463	-0.0227	0.2140	0.031 **	0.0702
<i>HHI</i>	-28.313	0.517	-8.4321	-37.639	0.186	-12.350
<i>phd_ma</i>	0.0636	0.016 **	0.0189	-0.0023	0.908	-0.0008
<i>ipicsec</i>	0.0052	0.553	0.0015	0.0030	0.705	0.0010

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE2: Wald $\chi^2(6) = 22.14$ Prob > $\chi^2 = 0.0011$

For PCRE2: Wald $\chi^2(6) = 18.46$ Prob > $\chi^2 = 0.0052$

The PDRE2 model focuses on the relationship between product innovation and *internal R&D expenditure*, which is shown in Table 57. In this model, independent variables are not statistically significant at 10% level, except the *number of highly educated R&D personnel*. Hence, the null hypothesis, H_{1a0} , is not rejected. The *number of highly educated R&D personnel* is statistically significant at 5% level. It means that a 1 percent increase in the value of the *number of highly educated R&D*

personnel, on average, leads to an increase of 1.89 percent in the likelihood of occurrence of product innovation.

The PCRE2 model focuses on the relationship between process innovation and *internal R&D expenditure*, which is shown in Table 57. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity* and *turnover*. Hence, the null hypothesis, $H3a_0$, is not rejected. *R&D personnel intensity* and *turnover* are statistically significant at the 5% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.57 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 7.02 percent in the likelihood of occurrence of process innovation.

Regression results of PDRE3 and PCRE3 models include coefficient, p-value, and average marginal effect, which are shown in Table 58. These models analyze the effect of *external R&D expenditure* on the probability of product and process innovations, respectively.

Table 58: Regression Results of PDRE3 and PCRE3 Models – C-20

Variable Name	PDRE3			PCRE3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpD</i>	-0.0430	0.042 **	-0.0127	-0.0257	0.214	-0.0084
<i>rdperint</i>	1.7076	0.090 *	0.5053	2.0065	0.011 **	0.6575
<i>IntoverD</i>	0.0084	0.918	0.0025	0.2495	0.003 ***	0.0817
<i>HHI</i>	-27.048	0.534	-8.0040	-37.252	0.194	-12.206
<i>phd_ma</i>	0.0719	0.005 ***	0.0213	0.0003	0.989	0.0001
<i>ipicsec</i>	0.0055	0.505	0.0016	0.0033	0.675	0.0011

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE3: Wald $\chi^2(6) = 35.78$ Prob > $\chi^2 = 0.0000$

For PCRE3: Wald $\chi^2(6) = 18.69$ Prob > $\chi^2 = 0.0047$

The PDRE3 model focuses on the relationship between product innovation and *external R&D expenditure*, which is shown in Table 58. In this model, independent variables are not statistically significant at 10% level, except *external R&D expenditure*, *R&D personnel intensity*, and the *number of highly educated R&D personnel*. *External R&D expenditure* is statistically significant at the 5% level but the

impact of it on the probability of product innovation is negative. Hence, the null hypothesis, $H1b_0$, is not rejected. It means that *external R&D expenditure* does not increase the likelihood of occurrence of product innovation, and it is harder to make a new product innovation with this type of expenditure in manufacture of chemicals and chemical products. In other words, there is fishing-out case where ϕ is less than 0. *R&D personnel intensity*, and the *number of highly educated R&D personnel* are statistically significant at 10% and 1% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *external R&D expenditure*, on average, leads to a decrease of 1.27 percent in the likelihood of occurrence of product innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.51 in the likelihood of occurrence of product innovation.
- A unit increase in the *number of highly educated R&D personnel*, on average, leads to an increase of 0.02 in the likelihood of occurrence of product innovation.

The PCRE3 model focuses on the relationship between process innovation and *external R&D expenditure*, which is shown in Table 58. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity* and *turnover*. Hence, the null hypothesis, $H3b_0$, is not rejected. *R&D personnel intensity* is statistically significant at 5% level. *Turnover* is statistically significant at the 1% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 8.17 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.66 in the likelihood of occurrence of process innovation.

Regression results of PDRE4 and PCRE4 models include coefficient, p-value, and average marginal effect, which are shown in Table 59. These models analyze the

effect of *external-domestic R&D expenditure* on the probability of product and process innovations, respectively.

Table 59: Regression Results of PDRE4 and PCRE4 Models – C-20

Variable Name	PDRE4			PCRE4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpdomD</i>	-0.0353	0.081 *	-0.0105	-0.0198	0.303	-0.0065
<i>rdperint</i>	1.7156	0.084 *	0.5112	2.0109	0.010 **	0.6603
<i>IntoverD</i>	0.0054	0.947	0.0016	0.2469	0.003 ***	0.0811
<i>HHI</i>	-29.288	0.506	-8.7261	-38.517	0.179	-12.647
<i>phd_ma</i>	0.0705	0.005 ***	0.0210	0.0002	0.993	0.0001
<i>ipicsec</i>	0.0054	0.516	0.0016	0.0032	0.684	0.0010

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE4: Wald chi2(6)=53.49 Prob > chi2=0.0000

For PCRE4: Wald chi2(6)=18.89 Prob > chi2=0.0044

The PDRE4 model focuses on the relationship between product innovation and *external-domestic R&D expenditure*, which is shown in Table 59. In this model, independent variables are not statistically significant at 10% level, except *external-domestic R&D expenditure*, *R&D personnel intensity*, and the *number of highly educated R&D personnel*. *External-domestic R&D expenditure* is statistically significant at the 10% level but the impact of it on the probability of product innovation is negative. Hence, the null hypothesis, $H1c_0$, is not rejected. It means that *external-domestic R&D expenditure* does not increase the likelihood of occurrence of product innovation, and it is harder to make a new product innovation with this type of expenditure in manufacture of chemicals and chemical products. In other words, there is fishing-out case where ϕ is less than 0. *R&D personnel intensity*, and the *number of highly educated R&D personnel* are statistically significant at 10% and 1% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *external R&D expenditure*, on average, leads to a decrease of 1.05 percent in the likelihood of occurrence of product innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.51 in the likelihood of occurrence of product innovation.

- A unit increase in the *number of highly educated R&D personnel*, on average, leads to an increase of 0.02 in the likelihood of occurrence of product innovation.

The PCRE4 model focuses on the relationship between process innovation and *external-domestic R&D expenditure*, which is shown in Table 59. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity* and *turnover*. Hence, the null hypothesis, $H3c_0$, is not rejected. *R&D personnel intensity* is statistically significant at 5% level. *Turnover* is statistically significant at the 1% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 8.11 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.66 in the likelihood of occurrence of process innovation.

Regression results of PDRE5 and PCRE5 models include coefficient, p-value, and average marginal effect, which are shown in Table 60. These models analyze the effect of *external-foreign R&D expenditure* on the probability of product and process innovations, respectively.

Table 60: Regression Results of PDRE5 and PCRE5 Models – C-20

Variable Name	PDRE5			PCRE5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpforD</i>	-0.0787	0.053 **	-0.0232	-0.0176	0.628	-0.0058
<i>rdperint</i>	1.5035	0.117	0.4427	1.9542	0.012 **	0.6428
<i>IntoverD</i>	0.0003	0.998	0.0001	0.2439	0.005 ***	0.0802
<i>HHI</i>	-21.663	0.609	-6.3793	-37.120	0.193	-12.210
<i>phd_ma</i>	0.0801	0.001 ***	0.0236	0.0011	0.957	0.0004
<i>ipicsec</i>	0.0056	0.514	0.0016	0.0030	0.704	0.0010

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE5: Wald $\chi^2(6) = 29.07$ Prob > $\chi^2 = 0.0001$

For PCRE5: Wald $\chi^2(6) = 18.12$ Prob > $\chi^2 = 0.0059$

The PDRE5 model focuses on the relationship between product innovation and *external-foreign R&D expenditure*, which is shown in Table 60. In this model, independent variables are not statistically significant at 10% level, except *external-*

foreign R&D expenditure and the *number of highly educated R&D personnel*. *External-foreign R&D expenditure* is statistically significant at the 5% level but the impact of it on the probability of product innovation is negative. Hence, the null hypothesis, $H1d_0$, is rejected. It means that *external-foreign R&D expenditure* does not increase the likelihood of occurrence of product innovation, and it is harder to make a new product innovation with this type of expenditure in manufacture of chemicals and chemical products. In other words, there is fishing-out case where ϕ is less than 0. The *number of highly educated R&D personnel* is statistically significant at the 1% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *external-foreign R&D expenditure*, on average, leads to a decrease of 2.32 percent in the likelihood of occurrence of product innovation.
- A unit increase in the *number of highly educated R&D personnel*, on average, leads to an increase of 0.024 in the likelihood of occurrence of product innovation.

The PCRE5 model focuses on the relationship between process innovation and *external-foreign R&D expenditure*, which is shown in Table 60. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity* and *turnover*. Hence, the null hypothesis, $H3d_0$, is not rejected. *R&D personnel intensity* is statistically significant at 5% level. *Turnover* is statistically significant at the 1% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 8.02 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.64 in the likelihood of occurrence of process innovation.

Regression results of PDRI1 and PCRI1 models include coefficient, p-value, and average marginal effect, which are shown in Table 61. These models analyze the

effect of *total R&D intensity* on the probability of product and process innovations, respectively.

Table 61: Regression Results of PDRI1 and PCRI1 Models – C-20

Variable Name	PDRI1			PCRI1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>totrdint</i>	-0.3158	0.478	-0.0950			
<i>rdperint</i>	1.6799	0.153	0.5053			
<i>IntoverD</i>	-0.0050	0.954	-0.0015			
<i>HHI</i>	-31.227	0.485	-9.3928			
<i>phd_ma</i>	0.0687	0.002 ***	0.0207			
<i>ipicsec</i>	0.0049	0.569	0.0015			

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI1: Wald chi2(6)=64.71 Prob > chi2=0.0000

For PCRI1: Wald chi2(6)=89.81 Prob > chi2=0.0000 Convergence not achieved.

The PDRI1 model focuses on the relationship between product innovation and *total R&D intensity*, which is shown in Table 61. In this model, independent variables are not statistically significant at the 10% level, except the *number of highly educated R&D personnel*. Hence, the null hypothesis, H_{20} , is rejected. The *number of highly educated R&D personnel* is statistically significant at the 1% level. It means that a unit increase in the *number of highly educated R&D personnel*, on average, leads to an increase of 0.021 in the likelihood of occurrence of product innovation.

The PCRI1 model focuses on the relationship between process innovation and *total R&D intensity*, which is shown in Table 61. Because convergence was not achieved during the analysis and 4 of 6 individual z-statistics (not shown here) is not statistically significant, the PCRI1 model is not shown here. Hence, the null hypothesis, H_{40} , could not be tested for manufacture of chemicals and chemical products.

Regression results of PDRI2 and PCRI2 models include coefficient, p-value, and average marginal effect, which are shown in Table 62. These models analyze the effect of *internal R&D intensity* on the probability of product and process innovations, respectively.

The PDRI2 model focuses on the relationship between product innovation and *internal R&D intensity*, which is shown in Table 62. In this model, independent

variables are not statistically significant at the 10% level, except the *number of highly educated R&D personnel*. Hence, the null hypothesis, $H2a_0$, is not rejected. The *number of highly educated R&D personnel* is statistically significant at 1% level. It means that a unit increase in the *number of highly educated R&D personnel*, on average, leads to an increase of 0.021 in the likelihood of occurrence of product innovation.

Table 62: Regression Results of PDRI2 and PCRI2 Models – C-20

Variable Name	PDRI2			PCRI2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>intrdint</i>	-0.2783	0.527	-0.0837	2.5662	0.214	0.8386
<i>rdperint</i>	1.6513	0.157	0.4967	1.4010	0.189	0.4578
<i>IntoverD</i>	-0.0048	0.955	-0.0014	0.2484	0.005 ***	0.0812
<i>HHI</i>	-31.220	0.485	-9.3900	-37.821	0.186	-12.359
<i>phd_ma</i>	0.0687	0.002 ***	0.0207	-0.0001	0.996	-0.00004
<i>ipicsec</i>	0.0049	0.569	0.0015	0.0030	0.707	0.0010

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI2: Wald $\chi^2(6) = 77.19$ Prob > $\chi^2 = 0.0000$

For PCRI2: Wald $\chi^2(6) = 19.60$ Prob > $\chi^2 = 0.0033$

The PCRI2 model focuses on the relationship between process innovation and *internal R&D intensity*, which is shown in Table 62. In this model, independent variables are not statistically significant at the 10% level, except *turnover*. Hence, the null hypothesis, $H4a_0$, is not rejected. *Turnover* is statistically significant at the 1% level. It means that a 1 percent increase in the value of *turnover*, on average, leads to an increase of 8.12 percent in the likelihood of occurrence of process innovation.

Regression results of PDRI3 and PCRI3 models include coefficient, p-value, and average marginal effect, which are shown in Table 63. These models analyze the effect of *external R&D intensity* on the probability of product and process innovations, respectively.

The PDRI3 model focuses on the relationship between product innovation and *external R&D intensity*, which is shown in Table 63. In this model, independent variables are not statistically significant at the 10% level, except the *number of highly educated R&D personnel*. Hence, the null hypothesis, $H2b_0$, is not rejected. The *number of highly educated R&D personnel* is statistically significant at the 1% level. It means that a unit increase in the *number of highly educated R&D personnel*, on

average, leads to an increase of 0.021 in the likelihood of occurrence of product innovation.

Table 63: Regression Results of PDRI3 and PCRI3 Models – C-20

Variable Name	PDRI3			PCRI3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extrdint</i>	-3.6267	0.442	-1.0893	0.2149	0.954	0.0707
<i>rdperint</i>	1.5677	0.101	0.4708	1.9630	0.011 **	0.6456
<i>IntoverD</i>	-0.0061	0.943	-0.0018	0.2415	0.005 ***	0.0794
<i>HHI</i>	-31.300	0.485	-9.4006	-38.906	0.173	-12.795
<i>phd_ma</i>	0.0688	0.002 ***	0.0207	0.0005	0.981	0.0002
<i>ipicsec</i>	0.0048	0.577	0.0014	0.0029	0.716	0.0010

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI3: Wald chi2(6)=19.80 Prob > chi2=0.0030

For PCRI3: Wald chi2(6)=18.27 Prob > chi2=0.0056

The PCRI3 model focuses on the relationship between process innovation and *external R&D intensity*, which is shown in Table 63. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity* and *turnover*. Hence, the null hypothesis, $H4b_0$, is not rejected. *R&D personnel intensity* is statistically significant at 5% level. *Turnover* is statistically significant at the 1% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 7.94 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.65 in the likelihood of occurrence of process innovation.

Regression results of PDRI4 and PCRI4 models include coefficient, p-value, and average marginal effect, which are shown in Table 64. These models analyze the effect of *external-domestic R&D intensity* on the probability of product and process innovations, respectively.

The PDRI4 model focuses on the relationship between product innovation and *external-domestic R&D intensity*, which is shown in Table 64. In this model, independent variables are not statistically significant at the 10% level, except the *number of highly educated R&D personnel*. Hence, the null hypothesis, $H2c_0$, is not rejected. The *number of highly educated R&D personnel* is statistically significant at

the 1% level. It means that a unit increase in the *number of highly educated R&D personnel*, on average, leads to an increase of 0.021 in the likelihood of occurrence of product innovation.

The PCRI4 model focuses on the relationship between process innovation and *external-domestic R&D intensity*, which is shown in Table 64. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity* and *turnover*. Hence, the null hypothesis, $H4c_0$, is not rejected. *R&D personnel intensity* is statistically significant at 5% level. *Turnover* is statistically significant at the 1% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 7.93 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.65 in the likelihood of occurrence of process innovation.

Table 64: Regression Results of PDRI4 and PCRI4 Models – C-20

Variable Name	PDRI4			PCRI4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extdomrdint</i>	-3.8457	0.419	-1.1550	-0.3157	0.934	-0.1038
<i>rdperint</i>	1.5727	0.101	0.4723	1.9652	0.011 **	0.6463
<i>IntoverD</i>	-0.0061	0.943	-0.0018	0.2413	0.005 ***	0.0793
<i>HHI</i>	-31.354	0.484	-9.4164	-38.918	0.173	-12.800
<i>phd_ma</i>	0.0688	0.002 ***	0.0206	0.0005	0.981	0.0002
<i>ipicsec</i>	0.0048	0.577	0.0014	0.0029	0.716	0.0009

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI4: Wald $\chi^2(6)=19.79$ Prob > $\chi^2=0.0030$

For PCRI4: Wald $\chi^2(6)=18.36$ Prob > $\chi^2=0.0054$

Regression results of PDRI5 and PCRI5 models include coefficient, p-value, and average marginal effect, which are shown in Table 65. These models analyze the effect of *external-foreign R&D intensity* on the probability of product and process innovations, respectively.

The PDRI5 model focuses on the relationship between product innovation and *external-foreign R&D intensity*, which is shown in Table 65. In this model, independent variables are not statistically significant at the 10% level, except *R&D*

personnel intensity and the *number of highly educated R&D personnel*. Hence, the null hypothesis, $H2d_0$, is not rejected. *R&D personnel intensity* and the *number of highly educated R&D personnel* are statistically significant at 10% and 1% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.47 in the likelihood of occurrence of product innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.021 in the likelihood of occurrence of product innovation.

Table 65: Regression Results of PDRI5 and PCRI5 Models – C-20

Variable Name	PDRI5			PCRI5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extfrgrdint</i>	46.378	0.321	13.920	123.183	0.014 **	40.400
<i>rdperint</i>	1.5479	0.099 *	0.4646	2.0022	0.010 **	0.6566
<i>IntoverD</i>	-0.0028	0.974	-0.0008	0.2434	0.005 ***	0.0798
<i>HHI</i>	-31.649	0.481	-9.4990	-40.008	0.162	-13.121
<i>phd_ma</i>	0.0685	0.002 ***	0.0206	-0.0001	0.995	0.0000
<i>ipicsec</i>	0.0048	0.578	0.0014	0.0027	0.733	0.0009

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI5: Wald $\chi^2(6)=19.48$ Prob > $\chi^2=0.0034$

For PCRI5: Wald $\chi^2(6)=22.06$ Prob > $\chi^2=0.0012$

The PCRI5 model focuses on the relationship between process innovation and *external-foreign R&D intensity*, which is shown in Table 65. In this model, independent variables are not statistically significant at 10% level, except *external-foreign R&D intensity*, *R&D personnel intensity*, and *turnover*. *External-foreign R&D intensity* is statistically significant at 5% level. Hence, the null hypothesis, $H4d_0$, is rejected. *R&D personnel intensity* and *turnover* are statistically significant at the 5% and 1% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external-foreign R&D intensity*, on average, leads to an increase of 40.4 in the likelihood of occurrence of process innovation.

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.66 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 7.998 percent in the likelihood of occurrence of process innovation.

According to the analysis of the manufacture of chemicals and chemical products, there are many findings in terms of product innovation. These are:

- R&D expenditure variables except total and internal are statistically significant but have negative effects on the likelihood of occurrence of product innovation in Turkish manufacturing industry. In this result, R&D expenditure variables do not meet the hypotheses.
- R&D intensity variables are not statistically significant at 10% level.
- The other independent variables are interpreted by focusing on the PDRE1 and PDRI1 models. Because these models cover *total R&D expenditures*. According to the PDRE1 model and the PDRI1 model, only the *number of highly educated R&D personnel* is statistically significant and has positive effect on the likelihood of occurrence of product innovation. It means that more highly educated R&D personnel increases the likelihood of occurrence of product innovation in the manufacture of chemicals and chemical products.

According to the analysis of the manufacture of chemicals and chemical products, there are many findings in terms of process innovation. These are:

- All R&D expenditure variables are not statistically significant at 10% level.
- R&D intensity variables except external-foreign are not statistically significant at 10% level. *External-foreign R&D intensity* is statistically significant and has positive effect on the likelihood of occurrence of process innovation.
- The other independent variables are interpreted by focusing on the PCRE1 and PCRI1 models. Because these models cover *total R&D expenditures*.

According to the PCRE1 model, these other independent variables except *R&D personnel intensity* and *turnover* are not statistically significant at 10% level. *R&D personnel intensity* and *turnover* are statistically significant and has positive effect on the likelihood of occurrence of process innovation. It means that more *R&D personnel intensity* and more *turnover* increase the likelihood of occurrence of process innovation in the manufacture of textiles. PCRI1 model is not statistically significant according to the Wald test.

Results of the analyses are also viewed by comparing product and process innovation in terms of the manufacture of chemicals and chemical products. These are:

- *External, external-domestic, and external-foreign R&D expenditure* affect only the likelihood of occurrence of product innovation negatively.
- *External-foreign R&D intensity* affects only the likelihood of occurrence of process innovation negatively.

4.2.2.4. Manufacture of Basic Pharmaceutical Products and Pharmaceutical Preparations, C-21 by NACE Rev. 2

Firms that are engaged in R&D in manufacture of basic pharmaceutical products and pharmaceutical preparations are analyzed with twenty models such as 10 product innovation models and 10 process innovation models.

Regression results of PDRE1 and PCRE1 models include coefficient, p-value, and average marginal effect, which are shown in Table 66. These models analyze the effect of *total R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE1 model focuses on the relationship between product innovation and *total R&D expenditure*, which is shown in Table 66. In this model, independent variables except *total R&D expenditure* and *HHI* are statistically significant such as *R&D personnel intensity* and *industrial production index by manufacturing industry* at 5% level, *turnover* and the *number of highly educated R&D personnel* at 10% level.

Hence, the null hypothesis, $H1_0$, is not rejected. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.92 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 7.62 percent in the likelihood of occurrence of product innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to a decrease of 0.01 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.32 percent in the likelihood of occurrence of product innovation.

Table 66: Regression Results of PDRE1 and PCRE1 Models – C-21

Variable Name	PDRE1			PCRE1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntrdexpD</i>	0.1137	0.435	0.0368	0.1288	0.062 *	0.0399
<i>rdperint</i>	2.8356	0.049 **	0.9170	3.3305	0.012 **	1.0324
<i>IntoverD</i>	0.2356	0.053 *	0.0762	0.2647	0.047 **	0.0821
<i>HHI</i>	58.068	0.190	18.778	91.164	0.021 **	28.260
<i>phd_ma</i>	-0.0298	0.057 *	-0.0097	-0.0283	0.100	-0.0088
<i>ipicsec</i>	0.0098	0.029 **	0.0032	0.0086	0.028 **	0.0027

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE1: Wald $\chi^2(6) = 23.13$ Prob > $\chi^2 = 0.0008$

For PCRE1: Wald $\chi^2(6) = 26.20$ Prob > $\chi^2 = 0.0002$

The PCRE1 model focuses on the relationship between process innovation and *total R&D expenditure*, which is shown in Table 66. In this model, independent variables except the *number of highly educated R&D personnel* are statistically significant such as *total R&D expenditure* at 10% level, *R&D personnel intensity*, *turnover*, *HHI*, and *industrial production index by manufacturing industry* at 10% level. Hence, the null hypothesis, $H3_0$, is rejected. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *total R&D expenditure*, on average, leads to an increase of 4 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 1.03 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 8.21 percent in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 28.26 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.27 percent in the likelihood of occurrence of process innovation.

Regression results of PDRE2 and PCRE2 models include coefficient, p-value, and average marginal effect, which are shown in Table 67. These models analyze the effect of *internal R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE2 model focuses on the relationship between product innovation and *internal R&D expenditure*, which is shown in Table 67. In this model, independent variables except *total R&D expenditure* and *HHI* are statistically significant such as *R&D personnel intensity* and the *number of highly educated R&D personnel* at 10% level, *turnover* and *industrial production index by manufacturing industry* at 5% level. Hence, the null hypothesis, $H1a_0$, is not rejected. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.92 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 8.06 percent in the likelihood of occurrence of product innovation.

- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to a decrease of 0.009 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.32 percent in the likelihood of occurrence of product innovation.

Table 67: Regression Results of PDRE2 and PCRE2 Models – C-21

Variable Name	PDRE2			PCRE2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntintrdexpD</i>	0.0890	0.530	0.0290	0.0871	0.144	0.0273
<i>rdperint</i>	2.8116	0.061 *	0.9147	3.3696	0.011 **	1.0541
<i>IntoverD</i>	0.2476	0.045 **	0.0806	0.2887	0.033 **	0.0903
<i>HHI</i>	57.147	0.198	18.592	90.255	0.021 **	28.233
<i>phd_ma</i>	-0.0287	0.068 *	-0.0093	-0.0266	0.120	-0.0083
<i>ipicsec</i>	0.0097	0.030 **	0.0032	0.0085	0.031 **	0.0026

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE2: Wald chi2(6)=22.34 Prob > chi2=0.0010

For PCRE2: Wald chi2(6)=25.51 Prob > chi2=0.0003

The PCRE2 model focuses on the relationship between process innovation and *internal R&D expenditure*, which is shown in Table 67. In this model, independent variables except *internal R&D expenditure* and the *number of highly educated R&D personnel* are statistically significant such as *R&D personnel intensity*, *turnover*, *HHI*, and *industrial production index by manufacturing industry* at 5% level. Hence, the null hypothesis, $H3a_0$, is not rejected. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 1.05 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 9.03 percent in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 28.23 in the likelihood of occurrence of process innovation.

- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.26 percent in the likelihood of occurrence of process innovation.

Regression results of PDRE3 and PCRE3 models include coefficient, p-value, and average marginal effect, which are shown in Table 68. These models analyze the effect of *external R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE3 model focuses on the relationship between product innovation and *external R&D expenditure*, which is shown in Table 68. In this model, independent variables except *HHI* are statistically significant such as *external R&D expenditure*, *R&D personnel intensity*, and the *number of highly educated R&D personnel* at 5% level, *turnover* and *industrial production index by manufacturing industry* at 1% level. Hence, the null hypothesis, $H1b_0$, is rejected. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *external R&D expenditure*, on average, leads to an increase of 1.83 percent in the likelihood of occurrence of product innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 1.04 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 9.23 percent in the likelihood of occurrence of product innovation.
- A unit increase in the *number of highly educated R&D personnel*, on average, leads to a decrease of 0.008 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.38 percent in the likelihood of occurrence of product innovation.

The PCRE3 model focuses on the relationship between process innovation and *external R&D expenditure*, which is shown in Table 68. In this model, independent

variables except the *number of highly educated R&D personnel* are statistically significant such as *external R&D expenditure* at 10% level, *HHI* and *industrial production index by manufacturing industry* at 5% level, and *R&D personnel intensity* and *turnover* are 1% level. Hence, the null hypothesis, $H3b_0$, is rejected. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *external R&D expenditure*, on average, leads to an increase of 1.28 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 1.19 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 11.05 percent in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 28.91 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.31 percent in the likelihood of occurrence of process innovation.

Table 68: Regression Results of PDRE3 and PCRE3 Models – C-21

Variable Name	PDRE3			PCRE3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpD</i>	0.0582	0.017 **	0.0183	0.0422	0.056 *	0.0128
<i>rdperint</i>	3.3149	0.021 **	1.0424	3.9308	0.004 ***	1.1929
<i>IntoverD</i>	0.2934	0.009 ***	0.0923	0.3641	0.005 ***	0.1105
<i>HHI</i>	62.246	0.177	19.574	95.249	0.012 **	28.906
<i>phd_ma</i>	-0.0280	0.018 **	-0.0088	-0.0254	0.115	-0.0077
<i>ipicsec</i>	0.0121	0.004 ***	0.0038	0.0102	0.012 **	0.0031

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE3: Wald $\chi^2(6)=31.92$ Prob > $\chi^2=0.0000$

For PCRE3: Wald $\chi^2(6)=30.73$ Prob > $\chi^2=0.0000$

Regression results of PDRE4 and PCRE4 models include coefficient, p-value, and average marginal effect, which are shown in Table 69. These models analyze the

effect of *external-domestic R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE4 model focuses on the relationship between product innovation and *external-domestic R&D expenditure*, which is shown in Table 69. In this model, independent variables except *HHI* are statistically significant such as *external-domestic R&D expenditure* and the *number of highly educated R&D personnel* at 10% level, *R&D personnel intensity*, *turnover*, and *industrial production index by manufacturing industry* at 5% level. Hence, the null hypothesis, $H1c_0$, is rejected. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *external-domestic R&D expenditure*, on average, leads to an increase of 1.53 percent in the likelihood of occurrence of product innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.97 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 8.7 percent in the likelihood of occurrence of product innovation.
- A unit increase in the *number of highly educated R&D personnel*, on average, leads to a decrease of 0.008 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.35 percent in the likelihood of occurrence of product innovation.

The PCRE4 model focuses on the relationship between process innovation and *external-domestic R&D expenditure*, which is shown in Table 69. In this model, independent variables except the *number of highly educated R&D personnel* are statistically significant such as *external-domestic R&D expenditure* at 10% level, *HHI* and *industrial production index by manufacturing industry* at 5% level, and *R&D personnel intensity* and *turnover* are 1% level. Hence, the null hypothesis, $H3c_0$, is rejected. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *external-domestic R&D expenditure*, on average, leads to an increase of 1.01 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 1.17 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 10.6 percent in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 29.01 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.28 percent in the likelihood of occurrence of process innovation.

Table 69: Regression Results of PDRE4 and PCRE4 Models – C-21

Variable Name	PDRE4			PCRE4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpdomD</i>	0.0474	0.071 *	0.0153	0.0325	0.098 *	0.0101
<i>rdperint</i>	3.0181	0.027 **	0.9733	3.7726	0.005 ***	1.1704
<i>IntoverD</i>	0.2699	0.015 **	0.0870	0.3415	0.007 ***	0.1059
<i>HHI</i>	61.921	0.175	19.970	93.522	0.015 **	29.015
<i>phd_ma</i>	-0.0231	0.085 *	-0.0075	-0.0223	0.173	-0.0069
<i>ipicsec</i>	0.0108	0.010 **	0.0035	0.0091	0.023 **	0.0028

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE4: Wald chi2(6)=29.40 Prob > chi2=0.0001

For PCRE4: Wald chi2(6)=28.88 Prob > chi2=0.0001

Regression results of PDRE5 and PCRE5 models include coefficient, p-value, and average marginal effect, which are shown in Table 70. These models analyze the effect of *external-foreign R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE5 model focuses on the relationship between product innovation and *external-foreign R&D expenditure*, which is shown in Table 70. In this model, independent variables except *external-foreign R&D expenditure* and *HHI* are statistically significant such as *R&D personnel intensity* and the *number of highly*

educated R&D personnel at 5% level, *turnover* and *industrial production index by manufacturing industry* at 1% level. Hence, the null hypothesis, $H1d_0$, is not rejected. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 1.1 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 9.99 percent in the likelihood of occurrence of product innovation.
- A unit increase in the *number of highly educated R&D personnel*, on average, leads to a decrease of 0.01 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.37 percent in the likelihood of occurrence of product innovation.

The PCRE5 model focuses on the relationship between process innovation and *external-foreign R&D expenditure*, which is shown in Table 70. In this model, independent variables except *external-foreign R&D expenditure* and the *number of highly educated R&D personnel* are statistically significant such as *R&D personnel intensity* and *turnover* at 1% level, *HHI* and *industrial production index by manufacturing industry* at 5% level. Hence, the null hypothesis, $H1d_0$, is not rejected. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 1.21 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 11.28 percent in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 28.37 in the likelihood of occurrence of process innovation.

- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.29 percent in the likelihood of occurrence of process innovation.

Table 70: Regression Results of PDRE5 and PCRE5 Models – C-21

Variable Name	PDRE5			PCRE5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpforD</i>	0.0553	0.102	0.0178	0.0242	0.542	0.0076
<i>rdperint</i>	3.4136	0.017 **	1.1023	3.8708	0.006 ***	1.2124
<i>IntoverD</i>	0.3095	0.006 ***	0.0999	0.3602	0.007 ***	0.1128
<i>HHI</i>	54.448	0.237	17.581	90.582	0.020 **	28.373
<i>phd_ma</i>	-0.0301	0.015 **	-0.0097	-0.0254	0.162	-0.0079
<i>ipicsec</i>	0.0113	0.007 ***	0.0037	0.0092	0.024 **	0.0029

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE5: Wald chi2(6)=28.42 Prob > chi2=0.0001

For PCRE5: Wald chi2(6)=27.52 Prob > chi2=0.0001

Regression results of PDRI1 and PCRI1 models include coefficient, p-value, and average marginal effect, which are shown in Table 71. These models analyze the effect of *total R&D intensity* on the probability of product and process innovations, respectively.

The PDRI1 model focuses on the relationship between product innovation and *total R&D intensity*, which is shown in Table 71. In this model, independent variables except *total R&D intensity* and *HHI* are statistically significant such as *R&D personnel intensity* at 10% level, the *number of highly educated R&D personnel* and *industrial production index by manufacturing industry* at 5% level, and *turnover* at 1% level. Hence, the null hypothesis, H_{20} , is not rejected. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.87 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 10.97 percent in the likelihood of occurrence of product innovation.
- A unit increase in the *number of highly educated R&D personnel*, on average, leads to a decrease of 0.009 in the likelihood of occurrence of product innovation.

- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.34 percent in the likelihood of occurrence of product innovation.

Table 71: Regression Results of PDRI1 and PCRI1 Models – C-21

Variable Name	PDRI1			PCRI1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>totrdint</i>	3.6040	0.159	1.1699	7.5636	0.001 ***	2.2701
<i>rdperint</i>	2.6818	0.071 *	0.8705	2.8949	0.033 **	0.8689
<i>IntoverD</i>	0.3379	0.004 ***	0.1097	0.4397	0.002 ***	0.1320
<i>HHI</i>	61.708	0.162	20.030	96.925	0.017 **	29.090
<i>phd_ma</i>	-0.0279	0.040 **	-0.0090	-0.0317	0.063 *	-0.0095
<i>ipicsec</i>	0.0106	0.019 **	0.0034	0.0102	0.008 ***	0.0031

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI1: Wald chi2(6)=21.32 Prob > chi2=0.0016

For PCRI1: Wald chi2(6)=25.83 Prob > chi2=0.0002

The PCRI1 model focuses on the relationship between process innovation and *total R&D intensity*, which is shown in Table 71. In this model, independent variables are statistically significant such as *total R&D intensity*, *turnover*, and *industrial production index by manufacturing industry* at 1% level, *R&D personnel intensity* and *HHI* at 5% level, and the *number of highly educated R&D personnel* at 10% level. Hence, the null hypothesis, H_{40} , is rejected. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *total R&D intensity*, on average, leads to an increase of 2.27 in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.87 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 13.2 percent in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 29.09 in the likelihood of occurrence of process innovation.

- A unit increase in the *number of highly educated R&D personnel*, on average, leads to a decrease of 0.01 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.31 percent in the likelihood of occurrence of process innovation.

Regression results of PDRI2 and PCRI2 models include coefficient, p-value, and average marginal effect, which are shown in Table 72. These models analyze the effect of *internal R&D intensity* on the probability of product and process innovations, respectively.

Table 72: Regression Results of PDRI2 and PCRI2 Models – C-21

Variable Name	PDRI2			PCRI2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>intrdint</i>	3.5172	0.350	1.1475	7.7992	0.006 ***	2.3680
<i>rdperint</i>	2.4757	0.103	0.8077	2.5658	0.046 **	0.7790
<i>IntoverD</i>	0.3230	0.006 ***	0.1054	0.4157	0.002 ***	0.1262
<i>HHI</i>	57.241	0.195	18.675	91.278	0.024 **	27.713
<i>phd_ma</i>	-0.0268	0.047 **	-0.0087	-0.0300	0.071 *	-0.0091
<i>ipicsec</i>	0.0101	0.027 **	0.0033	0.0097	0.012 **	0.0029

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI2: Wald chi2(6)=20.38 Prob > chi2=0.0024

For PCRI2: Wald chi2(6)=25.49 Prob > chi2=0.0003

The PDRI2 model focuses on the relationship between product innovation and *internal R&D intensity*, which is shown in Table 72. In this model, independent variables except *internal R&D intensity*, *R&D personnel intensity*, and *HHI* are statistically significant such as *turnover* at 1% level, the *number of highly educated R&D personnel* and *industrial production index by manufacturing industry* at 5% level. Hence, the null hypothesis, *H2a0*, is not rejected.

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 10.54 percent in the likelihood of occurrence of product innovation.
- A unit increase in the *number of highly educated R&D personnel*, on average, leads to a decrease of 0.009 in the likelihood of occurrence of product innovation.

- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.33 percent in the likelihood of occurrence of product innovation.

The PCRI2 model focuses on the relationship between process innovation and *internal R&D intensity*, which is shown in Table 72. In this model, independent variables are statistically significant such as *internal R&D intensity* and *turnover* at 1% level, *R&D personnel intensity*, *HHI*, and *industrial production index by manufacturing industry* at 5% level, the *number of highly educated R&D personnel* at 10% level. Hence, the null hypothesis, $H4a_0$, is rejected. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *internal R&D intensity*, on average, leads to an increase of 2.37 in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.78 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 12.62 percent in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 27.71 in the likelihood of occurrence of process innovation.
- A unit increase in the *number of highly educated R&D personnel*, on average, leads to a decrease of 0.009 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.29 percent in the likelihood of occurrence of process innovation.

Regression results of PDRI3 and PCRI3 models include coefficient, p-value, and average marginal effect, which are shown in Table 73. These models analyze the effect of *external R&D intensity* on the probability of product and process innovations, respectively.

Table 73: Regression Results of PDRI3 and PCRI3 Models – C-21

Variable Name	PDRI3			PCRI3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extrdint</i>	4.5782	0.055 *	1.5019	12.859	0.002 ***	3.9722
<i>rdperint</i>	3.3458	0.025 **	1.0976	4.2215	0.004 ***	1.3040
<i>IntoverD</i>	0.3172	0.006 ***	0.1041	0.3976	0.003 ***	0.1228
<i>HHI</i>	61.583	0.170	20.203	98.612	0.012 **	30.461
<i>phd_ma</i>	-0.0258	0.063 *	-0.0084	-0.0271	0.126	-0.0084
<i>ipicsec</i>	0.0101	0.021 **	0.0033	0.0093	0.021 **	0.0029

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI3: Wald $\chi^2(6) = 24.35$ Prob > $\chi^2 = 0.0004$

For PCRI3: Wald $\chi^2(6) = 29.54$ Prob > $\chi^2 = 0.0000$

The PDRI3 model focuses on the relationship between product innovation and *external R&D intensity*, which is shown in Table 73. In this model, independent variables except *HHI* are statistically significant such as *external R&D intensity* and the *number of highly educated R&D personnel* at 10% level, *R&D personnel intensity* and *industrial production index by manufacturing industry* at 5% level, and *turnover* at 1% level. Hence, the null hypothesis, H_{2b_0} , is rejected. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in *external R&D intensity*, on average, leads to an increase of 1.5 in the likelihood of occurrence of product innovation.
- A unit increase in *R&D personnel intensity*, on average, leads to an increase of 1.1 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 10.41 percent in the likelihood of occurrence of product innovation.
- A unit increase in the *number of highly educated R&D personnel*, on average, leads to a decrease of 0.008 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.33 percent in the likelihood of occurrence of product innovation.

The PCRI3 model focuses on the relationship between process innovation and *external R&D intensity*, which is shown in Table 73. In this model, independent variables except the *number of highly educated R&D personnel* are statistically significant such as *external R&D intensity*, *R&D personnel intensity*, and *turnover* at 1% level, *HHI* and *industrial production index by manufacturing industry* at 5% level. Hence, the null hypothesis, $H4b_0$, is rejected. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external R&D intensity*, on average, leads to an increase of 3.97 in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 1.3 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 12.28 percent in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 30.46 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.29 percent in the likelihood of occurrence of process innovation.

Regression results of PDRI4 and PCRI4 models include coefficient, p-value, and average marginal effect, which are shown in Table 74. These models analyze the effect of *external-domestic R&D intensity* on the probability of product and process innovations, respectively.

The PDRI4 model focuses on the relationship between product innovation and *external R&D intensity*, which is shown in Table 74. In this model, independent variables except *HHI* are statistically significant such as *external-domestic R&D intensity*, *R&D personnel intensity*, and *industrial production index by manufacturing industry* at 5% level, the *number of highly educated R&D personnel* at 10% level, and *turnover* at 1% level. Hence, the null hypothesis, $H2c_0$, is rejected. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in *external-domestic R&D intensity*, on average, leads to an increase of 1.63 in the likelihood of occurrence of product innovation.
- A unit increase in *R&D personnel intensity*, on average, leads to an increase of 1.08 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 10.27 percent in the likelihood of occurrence of product innovation.
- A unit increase in the *number of highly educated R&D personnel*, on average, leads to a decrease of 0.008 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.32 percent in the likelihood of occurrence of product innovation.

Table 74: Regression Results of PDRI4 and PCRI4 Models – C-21

Variable Name	PDRI4			PCRI4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extdomrdint</i>	4.9555	0.012 **	1.6283	11.483	0.003 ***	3.5803
<i>rdperint</i>	3.2929	0.027 **	1.0820	4.1075	0.004 ***	1.2807
<i>IntoverD</i>	0.3125	0.006 ***	0.1027	0.3803	0.004 ***	0.1186
<i>HHI</i>	60.517	0.176	19.885	95.818	0.014 **	29.876
<i>phd_ma</i>	-0.0253	0.066 *	-0.0083	-0.0255	0.138	-0.0079
<i>ipicsec</i>	0.0099	0.025 **	0.0032	0.0087	0.028 **	0.0027

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI4: Wald chi2(6)=25.62 Prob > chi2=0.0003

For PCRI4: Wald chi2(6)=28.09 Prob > chi2=0.0001

The PCRI4 model focuses on the relationship between process innovation and *external-domestic R&D intensity*, which is shown in Table 74. In this model, independent variables except the *number of highly educated R&D personnel* are statistically significant such as *external-domestic R&D intensity*, *R&D personnel intensity*, and *turnover* at 1% level, *HHI* and *industrial production index by manufacturing industry* at 5% level. Hence, the null hypothesis, $H4c_0$, is rejected. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external-domestic R&D intensity*, on average, leads to an increase of 3.58 in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 1.28 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 11.86 percent in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 29.88 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.27 percent in the likelihood of occurrence of process innovation.

Regression results of PDRI5 and PCRI5 models include coefficient, p-value, and average marginal effect, which are shown in Table 75. These models analyze the effect of *external-foreign R&D intensity* on the probability of product and process innovations, respectively.

Table 75: Regression Results of PDRI5 and PCRI5 Models – C-21

Variable Name	PDRI5			PCRI5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extfrgrdint</i>	18.235	0.073 *	5.9658	27.492	0.000 ***	2.4988
<i>rdperint</i>	3.4226	0.022 **	1.1197	4.2436	0.004 ***	1.3137
<i>lntoverD</i>	0.3253	0.005 ***	0.1064	0.4004	0.004 ***	0.1239
<i>HHI</i>	62.738	0.166	20.525	98.299	0.012 **	30.430
<i>phd_ma</i>	-0.0267	0.058 *	-0.0087	-0.0275	0.119	-0.0085
<i>ipicsec</i>	0.0106	0.018 **	0.0035	0.0098	0.016 **	0.0030

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI5: Wald chi2(6)=21.99 Prob > chi2=0.0012

For PCRI5: Wald chi2(6)=27.87 Prob > chi2=0.0001

The PDRI5 model focuses on the relationship between product innovation and *external-foreign R&D intensity*, which is shown in Table 75. In this model, independent variables except *HHI* are statistically significant such as *external-foreign R&D intensity* and the *number of highly educated R&D personnel* at 10% level, *R&D*

personnel intensity and *industrial production index by manufacturing industry* at 5% level, and *turnover* at 1% level. Hence, the null hypothesis, $H2d_0$, is rejected. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in *external-foreign R&D intensity*, on average, leads to an increase of 5.97 in the likelihood of occurrence of product innovation.
- A unit increase in *R&D personnel intensity*, on average, leads to an increase of 1.12 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 10.64 percent in the likelihood of occurrence of product innovation.
- A unit increase in the *number of highly educated R&D personnel*, on average, leads to a decrease of 0.009 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.35 percent in the likelihood of occurrence of product innovation.

The PCRI5 model focuses on the relationship between process innovation and *external-foreign R&D intensity*, which is shown in Table 75. In this model, independent variables except the *number of highly educated R&D personnel* are statistically significant such as *external-foreign R&D intensity*, *R&D personnel intensity*, and *turnover* at 1% level, *HHI* and *industrial production index by manufacturing industry* at 5% level. Hence, the null hypothesis, $H4d_0$, is rejected. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external-foreign R&D intensity*, on average, leads to an increase of 2.5 in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 1.31 in the likelihood of occurrence of process innovation.

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 12.39 percent in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 30.43 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.3 percent in the likelihood of occurrence of process innovation.

According to the analysis of the manufacture of basic pharmaceutical products and pharmaceutical preparations, there are many findings in terms of product innovation. These are:

- R&D expenditure variables except external and external-domestic are not statistically significant at 10% percent level. These both variables have positive effect on the likelihood of occurrence of product innovation in Turkish manufacturing industry. The most effective one is *external R&D expenditure*.
- R&D intensity variables except total and internal are statistically significant and have positive effect on the likelihood of occurrence of product innovation in Turkish manufacturing industry. The most effective one is *external-foreign R&D intensity*.
- The other independent variables are interpreted by focusing on the PDRE1 and PDRI1 models. Because these models cover *total R&D expenditures*. According to the PDRE1 model and the PDRI1 model, these other independent variables except *HHI* are statistically significant. These variables have positive effects on the likelihood of occurrence of product innovation, except the *number of highly educated R&D personnel*. It means that more *R&D personnel intensity*, more *turnover*, more *industrial production index by manufacturing industry* increases the likelihood of occurrence of product innovation, and it is vice versa for the *number of*

highly educated R&D personnel, in the manufacture of basic pharmaceutical products and pharmaceutical preparations.

According to the analysis of the manufacture of basic pharmaceutical products and pharmaceutical preparations, there are many findings in terms of process innovation. These are:

- R&D expenditure variables except internal and external-foreign are statistically significant and have positive effects on the likelihood of occurrence of process innovation. The most effective one is *total R&D expenditure*.
- All R&D intensity variables are statistically significant and have positive effect on the likelihood of occurrence of process innovation. The most effective one is *external R&D intensity*.
- The other independent variables are interpreted by focusing on the PCRE1 and PCRI1 models. Because these models cover *total R&D expenditures*. According to the PCRE1 model, these other independent variables except the *number of highly educated R&D personnel* are statistically significant and have positive effect on the likelihood of occurrence of process innovation. According to the PCRI1 model, these other independent variables are statistically significant, and they have positive effects on the likelihood of occurrence of process innovation, except the *number of highly educated R&D personnel*. It means that more of these other independent variables (except the *number of highly educated R&D personnel*) increase the likelihood of occurrence of process innovation. In addition, more highly educated R&D personnel decreases it.

Results of the analyses are also viewed by comparing product and process innovation in terms of the manufacture of basic pharmaceutical products and pharmaceutical preparations. These are:

- The impact of *external* and *external-domestic R&D expenditure* on the likelihood of occurrence of product innovation is greater than its impact on the likelihood of occurrence of process innovation.
- *Total R&D expenditure* affects only the likelihood of occurrence of process innovation.
- All R&D intensities affects the likelihood of occurrence of process innovation.
- The impact of *external* and *external-domestic R&D intensity* on the likelihood of occurrence of process innovation is greater than its impact on the likelihood of occurrence of product innovation.
- The impact of *external-foreign R&D intensity* on the likelihood of occurrence of product innovation is greater than its impact on the likelihood of occurrence of process innovation.

4.2.2.5. Manufacture of Rubber and Plastic Products, C-22 by NACE Rev. 2

Firms that are engaged in R&D in manufacture of rubber and plastic products are analyzed with twenty models such as 10 product innovation models and 10 process innovation models.

Regression results of PDRE1 and PCRE1 models include coefficient, p-value, and average marginal effect, which are shown in Table 76. These models analyze the effect of *total R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE1 model focuses on the relationship between product innovation and *total R&D expenditure*, which is shown in Table 76. In this model, independent variables except *turnover* and *HHI* are not statistically significant at 10% level. Hence, the null hypothesis, $H1_0$, is not rejected. *Turnover* and *HHI* are statistically significant at 10% and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 6.39 percent in the likelihood of occurrence of product innovation.
- An increase in *HHI* of 0.01, on average, leads to a decrease of 106.5 in the likelihood of occurrence of product innovation.

The PCRE1 model focuses on the relationship between process innovation and *total R&D expenditure*, which is shown in Table 76. In this model, independent variables except *turnover* and *R&D personnel intensity* are not statistically significant at 10% level. Hence, the null hypothesis, H_{30} , is not rejected. *Turnover* and *R&D personnel intensity* are statistically significant at 1% and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 10.32 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 1.81 in the likelihood of occurrence of process innovation.

Table 76: Regression Results of PDRE1 and PCRE1 Models – C-22

Variable Name	PDRE1			PCRE1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntrdexpD</i>	0.1045	0.140	0.0340	0.0346	0.625	0.0108
<i>rdperint</i>	1.6979	0.268	0.5518	5.7795	0.049 **	1.8106
<i>IntoverD</i>	0.1968	0.080 *	0.0639	0.3294	0.005 ***	0.1032
<i>HHI</i>	-327.73	0.015 **	-106.51	75.158	0.649	23.545
<i>phd_ma</i>	-0.0114	0.782	-0.0037	-0.0122	0.735	-0.0038
<i>ipicsec</i>	-0.0056	0.111	-0.0018	0.0069	0.251	0.0022

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE1: Wald chi2(6)=18.10 Prob > chi2=0.0060

For PCRE1: Wald chi2(6)=21.68 Prob > chi2=0.0014

Regression results of PDRE2 and PCRE2 models include coefficient, p-value, and average marginal effect, which are shown in Table 77. These models analyze the effect of *internal R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE2 model focuses on the relationship between product innovation and *internal R&D expenditure*, which is shown in Table 77. In this model, independent

variables except *turnover* and *HHI* are not statistically significant at 10% level. Hence, the null hypothesis, $H1a_0$, is not rejected. *Turnover* and *HHI* are statistically significant at the 10% and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 6.61 percent in the likelihood of occurrence of product innovation.
- An increase in *HHI* of 0.01, on average, leads to a decrease of 106.4 in the likelihood of occurrence of product innovation.

The PCRE2 model focuses on the relationship between process innovation and *internal R&D expenditure*, which is shown in Table 77. In this model, independent variables except *turnover* and *R&D personnel intensity* are not statistically significant at 10% level. Hence, the null hypothesis, $H3a_0$, is not rejected. *Turnover* and *R&D personnel intensity* are statistically significant at 1% and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 10.32 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 1.81 in the likelihood of occurrence of process innovation.

Table 77: Regression Results of PDRE2 and PCRE2 Models – C-22

Variable Name	PDRE2			PCRE2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntintrdexpD</i>	0.0904	0.195	0.0295	0.0339	0.637	0.0106
<i>rdperint</i>	1.8210	0.227	0.5947	5.7856	0.048 **	1.8129
<i>IntoverD</i>	0.2023	0.069 *	0.0661	0.3295	0.006 ***	0.1032
<i>HHI</i>	-325.748	0.015 **	-106.38	74.970	0.649	23.491
<i>phd_ma</i>	-0.0102	0.804	-0.0033	-0.0122	0.736	-0.0038
<i>ipicsec</i>	-0.0056	0.109	-0.0018	0.0069	0.252	0.0022

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE2: Wald $\chi^2(6) = 16.52$ Prob > $\chi^2 = 0.0112$

For PCRE2: Wald $\chi^2(6) = 21.64$ Prob > $\chi^2 = 0.0014$

Regression results of PDRE3 and PCRE3 models include coefficient, p-value, and average marginal effect, which are shown in Table 78. These models analyze the

effect of *external R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE3 model focuses on the relationship between product innovation and *external R&D expenditure*, which is shown in Table 78. In this model, independent variables except the *number of highly educated R&D personnel* and *industrial production index by manufacturing industry* are statistically significant such as *external R&D expenditure* and *R&D personnel intensity* at 10% level, *HHI* at 5% level, and *turnover* at 1% level. Hence, the null hypothesis, $H1b_0$, is rejected. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *external R&D expenditure*, on average, leads to an increase of 0.73 percent in the likelihood of occurrence of product innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.82 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 8.62 percent in the likelihood of occurrence of product innovation.
- An increase in *HHI* of 0.01, on average, leads to a decrease of 104.32 in the likelihood of occurrence of product innovation.

The PCRE3 model focuses on the relationship between process innovation and *external R&D expenditure*, which is shown in Table 78. In this model, independent variables except *turnover* and *R&D personnel intensity* are not statistically significant at 10% level. Hence, the null hypothesis, $H3b_0$, is not rejected. *Turnover* and *R&D personnel intensity* are statistically significant at 1% and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 11.02 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 1.94 in the likelihood of occurrence of process innovation.

Table 78: Regression Results of PDRE3 and PCRE3 Models – C-22

Variable Name	PDRE3			PCRE3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpD</i>	0.0219	0.072 *	0.0073	-0.0026	0.874	-0.0008
<i>rdperint</i>	2.4595	0.061 *	0.8150	6.1451	0.030 **	1.9372
<i>IntoverD</i>	0.2602	0.008 ***	0.0862	0.3497	0.001 ***	0.1102
<i>HHI</i>	-314.83	0.017 **	-104.32	74.557	0.646	23.503
<i>phd_ma</i>	-0.0035	0.928	-0.0012	-0.0090	0.807	-0.0028
<i>ipicsec</i>	-0.0055	0.101	-0.0018	0.0068	0.252	0.0021

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE3: Wald chi2(6)=18.55 Prob > chi2=0.0050

For PCRE3: Wald chi2(6)=21.13 Prob > chi2=0.0017

Regression results of PDRE4 and PCRE4 models include coefficient, p-value, and average marginal effect, which are shown in Table 79. These models analyze the effect of *external-domestic R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE4 model focuses on the relationship between product innovation and *external-domestic R&D expenditure*, which is shown in Table 79. In this model, independent variables except *external-domestic R&D expenditure* and the *number of highly educated R&D personnel* are statistically significant such as *R&D personnel intensity* and *industrial production index by manufacturing industry* at 10% level, *HHI* at 5% level, and *turnover* at 1% level. Hence, the null hypothesis, $H1_{C0}$, is rejected. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.82 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 8.57 percent in the likelihood of occurrence of product innovation.
- An increase in *HHI* of 0.01, on average, leads to a decrease of 103.76 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to a decrease of 0.19 percent in the likelihood of occurrence of product innovation.

The PCRE4 model focuses on the relationship between process innovation and *external-domestic R&D expenditure*, which is shown in Table 79. In this model, independent variables except *turnover* and *R&D personnel intensity* are not statistically significant at 10% level. Hence, the null hypothesis, $H3c_0$, is not rejected. *Turnover* and *R&D personnel intensity* are statistically significant at 1% and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 11 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 1.94 in the likelihood of occurrence of process innovation.

Table 79: Regression Results of PDRE4 and PCRE4 Models – C-22

Variable Name	PDRE4			PCRE4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpdomD</i>	0.0154	0.351	0.0051	-0.0042	0.837	-0.0013
<i>rdperint</i>	2.4680	0.066 *	0.8217	6.1546	0.030 **	1.9404
<i>IntoverD</i>	0.2575	0.008 ***	0.0857	0.3490	0.001 ***	0.1100
<i>HHI</i>	-311.65	0.018 **	-103.76	74.008	0.648	23.333
<i>phd_ma</i>	-0.0031	0.936	-0.0010	-0.0091	0.806	-0.0029
<i>ipicsec</i>	-0.0056	0.098 *	-0.0019	0.0068	0.254	0.0021

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE4: Wald $\chi^2(6)=16.57$ Prob > $\chi^2=0.0110$

For PCRE4: Wald $\chi^2(6)=21.06$ Prob > $\chi^2=0.0018$

Regression results of PDRE5 and PCRE5 models include coefficient, p-value, and average marginal effect, which are shown in Table 80. These models analyze the effect of *external-foreign R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE5 model focuses on the relationship between product innovation and *external-foreign R&D expenditure*, which is shown in Table 80. In this model, independent variables except the *number of highly educated R&D personnel* are statistically significant such as *external-foreign R&D expenditure* and *industrial production index by manufacturing industry* at 10% level, *R&D personnel intensity*, *turnover*, and *HHI* at 5% level. Hence, the null hypothesis, $H1d_0$, is rejected. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *external-foreign R&D expenditure*, on average, leads to an increase of 1.12 percent in the likelihood of occurrence of product innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.9 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 8.5 percent in the likelihood of occurrence of product innovation.
- An increase in *HHI* of 0.01, on average, leads to a decrease of 106.49 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to a decrease of 0.19 percent in the likelihood of occurrence of product innovation.

Table 80: Regression Results of PDRE5 and PCRE5 Models – C-22

Variable Name	PDRE5			PCRE5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpforD</i>	0.0337	0.086 *	0.0112	0.0008	0.985	0.0002
<i>rdperint</i>	2.7032	0.033 **	0.8976	6.1283	0.027 **	1.9309
<i>IntoverD</i>	0.2559	0.010 **	0.0850	0.3500	0.001 ***	0.1103
<i>HHI</i>	-320.71	0.016 **	-106.49	75.170	0.646	23.685
<i>phd_ma</i>	-0.0050	0.897	-0.0017	-0.0088	0.809	-0.0028
<i>ipicsec</i>	-0.0056	0.099 *	-0.0019	0.0068	0.248	0.0021

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE5: Wald chi2(6)=10.90 Prob > chi2=0.0914

For PCRE5: Wald chi2(6)=21.70 Prob > chi2=0.0014

The PCRE5 model focuses on the relationship between process innovation and *external-foreign R&D expenditure*, which is shown in Table 80. In this model, independent variables except *turnover* and *R&D personnel intensity* are not statistically significant at 10% level. Hence, the null hypothesis, *H3d0*, is not rejected. *Turnover* and *R&D personnel intensity* are statistically significant at 1% and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 11.03 percent in the likelihood of occurrence of process innovation.

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 1.94 in the likelihood of occurrence of process innovation.

Regression results of PDRI1 and PCRI1 models include coefficient, p-value, and average marginal effect, which are shown in Table 81. These models analyze the effect of *total R&D intensity* on the probability of product and process innovations, respectively.

Table 81: Regression Results of PDRI1 and PCRI1 Models – C-22

Variable Name	PDRI1			PCRI1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>totrdint</i>	-9.2943	0.150	-3.1237	-7.8148	0.358	-2.479
<i>rdperint</i>	4.4222	0.004 ***	1.4863	7.6543	0.026 **	2.428
<i>IntoverD</i>	0.2191	0.032 **	0.0736	0.3278	0.001 ***	0.104
<i>HHI</i>	-300.69	0.014 **	-101.06	85.988	0.578	27.27
<i>phd_ma</i>	0.0022	0.956	0.0007	-0.0046	0.900	-0.001
<i>ipicsec</i>	-0.0054	0.098 *	-0.0018	0.0070	0.236	0.002

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI1: Wald chi2(6)=12.51 Prob > chi2=0.0515

For PCRI1: Wald chi2(6)=19.68 Prob > chi2=0.0032

The PDRI1 model focuses on the relationship between product innovation and *total R&D intensity*, which is shown in Table 81. In this model, independent variables except *total R&D intensity* and the *number of highly educated R&D personnel* are statistically significant such as *R&D personnel intensity* at 1% level, *turnover* and *HHI* at 5% level, and *industrial production index by manufacturing industry* at 10% level. Hence, the null hypothesis, H_{20} , is not rejected. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 1.49 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 7.36 percent in the likelihood of occurrence of product innovation.
- An increase in *HHI* of 0.01, on average, leads to a decrease of 101.06 in the likelihood of occurrence of product innovation.

- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to a decrease of 0.18 percent in the likelihood of occurrence of product innovation.

The PCRI1 model focuses on the relationship between process innovation and *total R&D intensity*, which is shown in Table 81. In this model, independent variables except *turnover* and *R&D personnel intensity* are not statistically significant at 10% level. Hence, the null hypothesis, $H4_0$, is not rejected. *Turnover* and *R&D personnel intensity* are statistically significant at 1% and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 10.4 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 2.43 in the likelihood of occurrence of process innovation.

Regression results of PDRI2 and PCRI2 models include coefficient, p-value, and average marginal effect, which are shown in Table 82. These models analyze the effect of *internal R&D intensity* on the probability of product and process innovations, respectively.

The PDRI2 model focuses on the relationship between product innovation and *internal R&D intensity*, which is shown in Table 82. In this model, independent variables except *internal R&D intensity* and the *number of highly educated R&D personnel* are statistically significant such as *R&D personnel intensity* at 1% level, *turnover* and *HHI* at 5% level, and *industrial production index by manufacturing industry* at 10% level. Hence, the null hypothesis, $H2a_0$, is not rejected. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 1.52 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 7.36 percent in the likelihood of occurrence of product innovation.

- An increase in *HHI* of 0.01, on average, leads to a decrease of 100.65 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to a decrease of 0.18 percent in the likelihood of occurrence of product innovation.

The PCRI2 model focuses on the relationship between process innovation and *internal R&D intensity*, which is shown in Table 81. In this model, independent variables except *turnover* and *R&D personnel intensity* are not statistically significant at 10% level. Hence, the null hypothesis, $H4a_0$, is not rejected. *Turnover* and *R&D personnel intensity* are statistically significant at 1% and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 10.4 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 2.43 in the likelihood of occurrence of process innovation.

Table 82: Regression Results of PDRI2 and PCRI2 Models – C-22

Variable Name	PDRI2			PCRI2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>intrdint</i>	-9.7906	0.135	-3.2877	-7.6692	0.373	-2.4318
<i>rdperint</i>	4.5113	0.004 ***	1.5149	7.6126	0.026 **	2.4138
<i>IntoverD</i>	0.2192	0.032 **	0.0736	0.3287	0.001 ***	0.1042
<i>HHI</i>	-299.72	0.014 **	-100.65	86.289	0.576	27.361
<i>phd_ma</i>	0.0029	0.943	0.0010	-0.0045	0.902	-0.0014
<i>ipicsec</i>	-0.0054	0.099 *	-0.0018	0.0070	0.233	0.0022

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI2: Wald $\chi^2(6) = 12.80$ Prob > $\chi^2 = 0.0464$

For PCRI2: Wald $\chi^2(6) = 19.69$ Prob > $\chi^2 = 0.0021$

Regression results of PDRI3 and PCRI3 models include coefficient, p-value, and average marginal effect, which are shown in Table 83. These models analyze the effect of *external R&D intensity* on the probability of product and process innovations, respectively.

The PDRI3 model focuses on the relationship between product innovation and *external R&D intensity*, which is shown in Table 83. In this model, independent variables except *external R&D intensity*, the *number of highly educated R&D personnel*, and *industrial production index by manufacturing industry* are statistically significant such as *R&D personnel intensity* and *HHI* at 5% level, *turnover* at 1% level. Hence, the null hypothesis, $H2b_0$, is not rejected. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.84 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 8.8 percent in the likelihood of occurrence of product innovation.
- An increase in *HHI* of 0.01, on average, leads to a decrease of 102.86 in the likelihood of occurrence of product innovation.

Table 83: Regression Results of PDRI3 and PCRI3 Models – C-22

Variable Name	PDRI3			PCRI3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extrdint</i>	55.4744	0.253	18.386	-24.942	0.450	-7.8637
<i>rdperint</i>	2.5290	0.048 **	0.838	6.1756	0.027 **	1.9470
<i>lntoverD</i>	0.2653	0.007 ***	0.088	0.3485	0.001 ***	0.1099
<i>HHI</i>	-310.348	0.019 **	-102.86	73.659	0.650	23.223
<i>phd_ma</i>	-0.0021	0.958	-0.001	-0.0094	0.797	-0.0030
<i>ipicsec</i>	-0.0055	0.108	-0.002	0.0067	0.256	0.0021

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI3: Wald $\chi^2(6)=15.56$ Prob > $\chi^2=0.0163$

For PCRI3: Wald $\chi^2(6)=21.79$ Prob > $\chi^2=0.0013$

The PCRI3 model focuses on the relationship between process innovation and *external R&D intensity*, which is shown in Table 83. In this model, independent variables except *turnover* and *R&D personnel intensity* are not statistically significant at 10% level. Hence, the null hypothesis, $H4b_0$, is not rejected. *Turnover* and *R&D personnel intensity* are statistically significant at 1% and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 10.99 percent in the likelihood of occurrence of process innovation.

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 1.95 in the likelihood of occurrence of process innovation.

Regression results of PDRI4 and PCRI4 models include coefficient, p-value, and average marginal effect, which are shown in Table 84. These models analyze the effect of *external-domestic R&D intensity* on the probability of product and process innovations, respectively.

The PDRI4 model focuses on the relationship between product innovation and *external-domestic R&D intensity*, which is shown in Table 84. In this model, independent variables except *external-domestic R&D intensity*, the *number of highly educated R&D personnel*, and *industrial production index by manufacturing industry* are statistically significant such as *R&D personnel intensity* and *HHI* at 5% level, and *turnover* at 1% level. Hence, the null hypothesis, H_{2c0} , is not rejected. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.84 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 8.74 percent in the likelihood of occurrence of product innovation.
- An increase in *HHI* of 0.01, on average, leads to a decrease of 103.14 in the likelihood of occurrence of product innovation.

Table 84: Regression Results of PDRI4 and PCRI4 Models – C-22

Variable Name	PDRI4			PCRI4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extdomrdint</i>	49.681	0.311	16.493	-6.6240	0.835	-2.0875
<i>rdperint</i>	2.5246	0.049 **	0.8381	6.1403	0.028 **	1.9351
<i>IntoverD</i>	0.2633	0.007 ***	0.0874	0.3496	0.001 ***	0.1102
<i>HHI</i>	-310.68	0.018 **	-103.139	74.887	0.645	23.600
<i>phd_ma</i>	-0.0021	0.959	-0.0007	-0.0090	0.807	-0.0028
<i>ipicsec</i>	-0.0055	0.103	-0.0018	0.0068	0.252	0.0021

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI4: Wald $\chi^2(6) = 15.65$ Prob > $\chi^2 = 0.0158$

For PCRI4: Wald $\chi^2(6) = 21.70$ Prob > $\chi^2 = 0.0014$

The PCRI4 model focuses on the relationship between process innovation and *external-domestic R&D intensity*, which is shown in Table 84. In this model, independent variables except *turnover* and *R&D personnel intensity* are not statistically significant at 10% level. Hence, the null hypothesis, $H4c_0$, is not rejected. *Turnover* and *R&D personnel intensity* are statistically significant at 1% and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 11.02 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 1.94 in the likelihood of occurrence of process innovation.

Regression results of PDRI5 and PCRI5 models include coefficient, p-value, and average marginal effect, which are shown in Table 85. These models analyze the effect of *external-foreign R&D intensity* on the probability of product and process innovations, respectively.

Table 85: Regression Results of PDRI5 and PCRI5 Models – C-22

Variable Name	PDRI5			PCRI5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extfrgrdint</i>	194.426	0.177	64.792	-529.810	0.210	-166.700
<i>rdperint</i>	2.6536	0.035 **	0.8843	6.1254	0.028 **	1.9273
<i>IntoverD</i>	0.2540	0.011 **	0.0847	0.3529	0.001 ***	0.1110
<i>HHI</i>	-314.397	0.017 **	-104.772	67.0889	0.675	21.1089
<i>phd_ma</i>	-0.0040	0.919	-0.0013	-0.0096	0.790	-0.0030
<i>ipicsec</i>	-0.0055	0.108	-0.0018	0.0060	0.299	0.0019

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI5: Wald $\chi^2(6)=10.85$ Prob > $\chi^2=0.0932$

For PCRI5: Wald $\chi^2(6)=22.28$ Prob > $\chi^2=0.0011$

The PDRI5 model focuses on the relationship between product innovation and *external-foreign R&D intensity*, which is shown in Table 85. In this model, independent variables except *external-foreign R&D intensity*, the *number of highly educated R&D personnel*, and *industrial production index by manufacturing industry* are statistically significant such as *R&D personnel intensity*, *HHI*, and *turnover* at 5% level. Hence, the null hypothesis, $H2d_0$, is not rejected. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.88 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 8.47 percent in the likelihood of occurrence of product innovation.
- An increase in *HHI* of 0.01, on average, leads to a decrease of 104.77 in the likelihood of occurrence of product innovation.

The PCRI5 model focuses on the relationship between process innovation and *external-foreign R&D intensity*, which is shown in Table 85. In this model, independent variables except *turnover* and *R&D personnel intensity* are not statistically significant at 10% level. Hence, the null hypothesis, $H4d_0$, is not rejected. *Turnover* and *R&D personnel intensity* are statistically significant at 1% and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 11.1 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 1.93 in the likelihood of occurrence of process innovation.

According to the analysis of the manufacture of rubber and plastic products, there are many findings in terms of product innovation. These are:

- R&D expenditure variables except external and external-foreign are not statistically significant at 10% level and have positive effect on the likelihood of occurrence of product innovation in Turkish manufacturing industry. The most effective one is *external-foreign R&D expenditure*.
- R&D intensity variables are not statistically significant at 10% level.
- The other independent variables are interpreted by focusing on the PDRE1 and PDRI1 models. Because these models cover *total R&D expenditures*. According to the PDRE1 model, *turnover* and *HHI* are statistically significant and have positive and negative effects respectively on the likelihood of occurrence of product innovation. According to the PDRI1

model, these other independent variables except the *number of highly educated R&D personnel* are statistically significant and have negative effects except *R&D personnel intensity* and *turnover*. It means that more *R&D personnel intensity* and more *turnover* increase the likelihood of occurrence of product innovation, and more concentrated rubber and plastic products market and more *industrial production index by manufacturing industry* decrease it in the manufacture of rubber and plastic products.

According to the analysis of the manufacture of rubber and plastic products, there are many findings in terms of process innovation. These are:

- All R&D expenditure variables and all R&D intensity variables are not statistically significant at 10% level.
- The other independent variables are interpreted by focusing on the PCRE1 and PCRI1 models. Because these models cover *total R&D expenditures*. According to PCRE1 and PCRI1 models, *R&D personnel intensity* and *turnover* are statistically significant and have positive effect on the likelihood of occurrence of process innovation. It means that more R&D intensity and more *turnover* increase the likelihood of occurrence of process innovation in the manufacture of rubber and plastic products.

Results of the analyses are also viewed by comparing product and process innovation in terms of the manufacture of rubber and plastic products. These are:

- *External* and *external-foreign R&D expenditures* affects only the likelihood of occurrence of product innovation positively.

4.2.2.6. Manufacture of Other Non-Metallic Mineral Products, C-23 by NACE Rev. 2

Firms that are engaged in R&D in manufacture of other non-metallic mineral products are analyzed with twenty models such as 10 product innovation models and 10 process innovation models.

Regression results of PDRE1 and PCRE1 models include coefficient, p-value, and average marginal effect, which are shown in Table 86. These models analyze the effect of *total R&D expenditure* on the probability of product and process innovations, respectively.

Table 86: Regression Results of PDRE1 and PCRE1 Models – C-23

Variable Name	PDRE1			PCRE1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>lntrdexpD</i>	0.4242	0.000 ***	0.1309	0.2964	0.003 ***	0.1013
<i>rdperint</i>	-0.5412	0.121	-0.1670	-0.4911	0.133	-0.1679
<i>lnloverD</i>	-0.2674	0.026 **	-0.0825	-0.2873	0.014 **	-0.0982
<i>HHI</i>	148.091	0.852	45.697	167.950	0.766	57.406
<i>phd_ma</i>	-0.0553	0.294	-0.0171	-0.0582	0.155	-0.0199
<i>ipicsec</i>	0.0055	0.852	0.0017	0.0031	0.887	0.0010

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE1: Wald chi2(6)=24.26 Prob > chi2=0.0005

For PCRE1: Wald chi2(6)=32.70 Prob > chi2=0.0000

The PDRE1 model focuses on the relationship between product innovation and *total R&D expenditure*, which is shown in Table 86. In this model, independent variables except *total R&D expenditure* and *turnover* are not statistically significant at 10% level. *Total R&D expenditure* statistically significant at 1% level. Hence, the null hypothesis, $H1_0$, is rejected. *Turnover* is statistically significant at the 5% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *total R&D expenditure*, on average, leads to an increase of 13.09 percent in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to a decrease of 8.25 percent in the likelihood of occurrence of product innovation.

The PCRE1 model focuses on the relationship between process innovation and *total R&D expenditure*, which is shown in Table 86. In this model, independent variables except *total R&D expenditure* and *turnover* are not statistically significant at 10% level. *Total R&D expenditure* statistically significant at 1% level. Hence, the null hypothesis, $H3_0$, is rejected. *Turnover* is statistically significant at the 5% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *total R&D expenditure*, on average, leads to an increase of 10.13 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to a decrease of 9.82 percent in the likelihood of occurrence of process innovation.

Regression results of PDRE2 and PCRE2 models include coefficient, p-value, and average marginal effect, which are shown in Table 87. These models analyze the effect of *internal R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE2 model focuses on the relationship between product innovation and *internal R&D expenditure*, which is shown in Table 87. In this model, independent variables except *total R&D expenditure* and *turnover* are not statistically significant at 10% level. *Total R&D expenditure* statistically significant at 1% level. Hence, the null hypothesis, $H1a_0$, is rejected. *Turnover* is statistically significant at the 10% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *internal R&D expenditure*, on average, leads to an increase of 11.6 percent in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to a decrease of 6.22 percent in the likelihood of occurrence of product innovation.

The PCRE2 model focuses on the relationship between process innovation and *internal R&D expenditure*, which is shown in Table 87. In this model, independent variables except *internal R&D expenditure* and *turnover* are not statistically significant at 10% level. *Internal R&D expenditure* and *turnover* are statistically significant at the 5% level. Hence, the null hypothesis, $H3a_0$, is rejected. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *internal R&D expenditure*, on average, leads to an increase of 8.31 percent in the likelihood of occurrence of process innovation.

- 1 percent increase in the value of *turnover*, on average, leads to a decrease of 8.04 percent in the likelihood of occurrence of process innovation.

Table 87: Regression Results of PDRE2 and PCRE2 Models – C-23

Variable Name	PDRE2			PCRE2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntintrdexpD</i>	0.3702	0.000 ***	0.1160	0.2392	0.014 **	0.0831
<i>rdperint</i>	-0.3746	0.275	-0.1174	-0.4032	0.218	-0.1401
<i>IntoverD</i>	-0.1983	0.078 *	-0.0622	-0.2314	0.045 **	-0.0804
<i>HHI</i>	80.376	0.920	25.196	113.515	0.834	39.447
<i>phd_ma</i>	-0.0492	0.353	-0.0154	-0.0515	0.180	-0.0179
<i>ipicsec</i>	0.0029	0.922	0.0009	0.0012	0.954	0.0004

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE2: Wald chi2(6)=20.00 Prob > chi2=0.0028

For PCRE2: Wald chi2(6)=25.45 Prob > chi2=0.0003

Regression results of PDRE3 and PCRE3 models include coefficient, p-value, and average marginal effect, which are shown in Table 88. These models analyze the effect of *external R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE3 model focuses on the relationship between product innovation and *external R&D expenditure*, which is shown in Table 88. In this model, independent variables are not statistically significant at 10% level. Hence, the null hypothesis, $H1b_0$, is not rejected.

Table 88: Regression Results of PDRE3 and PCRE3 Models – C-23

Variable Name	PDRE3			PCRE3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpD</i>	0.0215	0.253	0.0073			
<i>rdperint</i>	0.1313	0.683	0.0449			
<i>IntoverD</i>	-0.0475	0.607	-0.0162			
<i>HHI</i>	-219.532	0.761	-75.038			
<i>phd_ma</i>	0.0194	0.666	0.0066			
<i>ipicsec</i>	-0.0065	0.810	-0.0022			

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE3: Wald chi2(6)=13.21 Prob > chi2=0.0398

For PCRE3: Wald chi2(6)=4.53 Prob > chi2=0.6050

The PCRE3 model focuses on the relationship between process innovation and *external R&D expenditure*, which is shown in Table 88. Because the Wald test and all individual z-statistics (not shown here) are not statistically significant, the PCRE3

model is not shown here. Hence, the null hypothesis, $H3b_0$, could not be tested for manufacture of other non-metallic mineral products.

Regression results of PDRE4 and PCRE4 models include coefficient, p-value, and average marginal effect, which are shown in Table 89. These models analyze the effect of *external-domestic R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE4 model focuses on the relationship between product innovation and *external-domestic R&D expenditure*, which is shown in Table 89. In this model, independent variables are not statistically significant at 10% level. Hence, the null hypothesis, $H1c_0$, is not rejected.

The PCRE4 model focuses on the relationship between process innovation and *external-domestic R&D expenditure*, which is shown in Table 89. Because the Wald test and all individual z-statistics (not shown here) are not statistically significant, the PCRE3 model is not shown here. Hence, the null hypothesis, $H3c_0$, could not be tested for manufacture of other non-metallic mineral products.

Table 89: Regression Results of PDRE4 and PCRE4 Models – C-23

Variable Name	PDRE4			PCRE4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpdomD</i>	0.0184	0.300	0.0063			
<i>rdperint</i>	0.1354	0.678	0.0463			
<i>IntoverD</i>	-0.0476	0.606	-0.0163			
<i>HHI</i>	-240.07	0.742	-82.128			
<i>phd_ma</i>	0.0222	0.615	0.0076			
<i>ipicsec</i>	-0.0074	0.785	-0.0025			

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE4: Wald $\chi^2(6) = 12.74$ Prob > $\chi^2 = 0.0473$

For PCRE4: Wald $\chi^2(6) = 4.48$ Prob > $\chi^2 = 0.6119$

Regression results of PDRE5 and PCRE5 models include coefficient, p-value, and average marginal effect, which are shown in Table 90. These models analyze the effect of *external-foreign R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE5 model focuses on the relationship between product innovation and *external-foreign R&D expenditure*, which is shown in Table 90. In this model,

independent variables are not statistically significant at 10% level. Hence, the null hypothesis, $H1d_0$, is not rejected.

Table 90: Regression Results of PDRE5 and PCRE5 Models – C-23

Variable Name	PDRE5			PCRE5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpforD</i>	0.0739	0.208	0.0254			
<i>rdperint</i>	0.1861	0.566	0.0639			
<i>IntoverD</i>	-0.0400	0.661	-0.0138			
<i>HHI</i>	-27.441	0.969	-9.4307			
<i>phd_ma</i>	0.0045	0.927	0.0015			
<i>ipicsec</i>	0.0004	0.987	0.0001			

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE5: Wald $\chi^2(6) = 13.26$ Prob > $\chi^2 = 0.0391$

For PCRE5: Wald $\chi^2(6) = 5.56$ Prob > $\chi^2 = 0.4740$

The PCRE5 model focuses on the relationship between process innovation and *external-foreign R&D expenditure*, which is shown in Table 90. Because the Wald test and all individual z-statistics (not shown here) are not statistically significant, the PCRE5 model is not shown here. Hence, the null hypothesis, $H3d_0$, could not be tested for manufacture of other non-metallic mineral products.

Regression results of PDRI1 and PCRI1 models include coefficient, p-value, and average marginal effect, which are shown in Table 91. These models analyze the effect of *total R&D intensity* on the probability of product and process innovations, respectively.

The PDRI1 model focuses on the relationship between product innovation and *total R&D intensity*, which is shown in Table 91. Because the Wald test and 5 of 6 individual z-statistics (not shown here) are not statistically significant, the PDRI1 model is not shown here. Hence, the null hypothesis, $H2_0$, could not be tested for manufacture of other non-metallic mineral products.

The PCRI1 model focuses on the relationship between process innovation and *total R&D intensity*, which is shown in Table 91. Because the Wald test and 5 of 6 individual z-statistics (not shown here) are not statistically significant, the PCRI1 model is not shown here. Hence, the null hypothesis, $H4_0$, could not be tested for manufacture of other non-metallic mineral products.

Table 91: Regression Results of PDRI1 and PCRI1 Models – C-23

Variable Name	PDRI1			PCRI1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>totrdint</i>						
<i>rdperint</i>						
<i>IntoverD</i>						
<i>HHI</i>						
<i>phd_ma</i>						
<i>ipicsec</i>						

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI1: Wald chi2(6)=4.35 Prob > chi2=0.6295

For PCRI1: Wald chi2(6)=4.41 Prob > chi2=0.6219

Regression results of PDRI2 and PCRI2 models include coefficient, p-value, and average marginal effect, which are shown in Table 92. These models analyze the effect of *internal R&D intensity* on the probability of product and process innovations, respectively.

The PDRI2 model focuses on the relationship between product innovation and *internal R&D intensity*, which is shown in Table 92. Because the Wald test and 5 of 6 individual z-statistics (not shown here) are not statistically significant, the PDRI2 model is not shown here. Hence, the null hypothesis, H_{2a0} , could not be tested for manufacture of other non-metallic mineral products.

Table 92: Regression Results of PDRI2 and PCRI2 Models – C-23

Variable Name	PDRI2			PCRI2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>intrdint</i>						
<i>rdperint</i>						
<i>IntoverD</i>						
<i>HHI</i>						
<i>phd_ma</i>						
<i>ipicsec</i>						

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI2: Wald chi2(6)=3.99 Prob > chi2=0.6783

For PCRI2: Wald chi2(6)=4.21 Prob > chi2=0.6488

The PCRI2 model focuses on the relationship between process innovation and *internal R&D intensity*, which is shown in Table 92. Because the Wald test and all individual z-statistics (not shown here) are not statistically significant, the PCRI2

model is not shown here. Hence, the null hypothesis, $H4a_0$, could not be tested for manufacture of other non-metallic mineral products.

Regression results of PDRI3 and PCRI3 models include coefficient, p-value, and average marginal effect, which are shown in Table 93. These models analyze the effect of *external R&D intensity* on the probability of product and process innovations, respectively.

The PDRI3 model focuses on the relationship between product innovation and *external R&D intensity*, which is shown in Table 93. Because the Wald test and 5 of 6 individual z-statistics (not shown here) are not statistically significant, the PDRI3 model is not shown here. Hence, the null hypothesis, $H2b_0$, could not be tested for manufacture of other non-metallic mineral products.

The PCRI3 model focuses on the relationship between process innovation and *external R&D intensity*, which is shown in Table 93. Because the Wald test and all individual z-statistics (not shown here) are not statistically significant, the PCRI3 model is not shown here. Hence, the null hypothesis, $H4b_0$, could not be tested for manufacture of other non-metallic mineral products.

Table 93: Regression Results of PDRI3 and PCRI3 Models – C-23

Variable Name	PDRI3			PCRI3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extrdint</i>						
<i>rdperint</i>						
<i>IntoverD</i>						
<i>HHI</i>						
<i>phd_ma</i>						
<i>ipicsec</i>						

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI3: Wald $\chi^2(6) = 9.33$ Prob > $\chi^2 = 0.1558$

For PCRI3: Wald $\chi^2(6) = 5.71$ Prob > $\chi^2 = 0.4566$

Regression results of PDRI4 and PCRI4 models include coefficient, p-value, and average marginal effect, which are shown in Table 94. These models analyze the effect of *external-domestic R&D intensity* on the probability of product and process innovations, respectively.

The PDRI4 model focuses on the relationship between product innovation and *external-domestic R&D intensity*, which is shown in Table 94. In this model, independent variables except *external-domestic R&D intensity* are not statistically significant at 10% level. *external-domestic R&D intensity* statistically significant at 5% level. Hence, the null hypothesis, $H2c_0$, is rejected. It means that a unit increase in the value of *external-domestic R&D intensity*, on average, leads to an increase of 42.21 in the likelihood of occurrence of process innovation.

Table 94: Regression Results of PDRI4 and PCRI4 Models – C-23

Variable Name	PDRI4			PCRI4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extdomrdint</i>	125.88	0.014 **	42.210			
<i>rdperint</i>	0.3027	0.392	0.1015			
<i>IntoverD</i>	-0.0266	0.796	-0.0089			
<i>HHI</i>	-225.46	0.764	-75.604			
<i>phd_ma</i>	0.0204	0.647	0.0069			
<i>ipicsec</i>	-0.0072	0.796	-0.0024			

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI4: Wald $\chi^2(6)=13.26$ Prob > $\chi^2=0.0390$

For PCRI4: Wald $\chi^2(6)=6.96$ Prob > $\chi^2=0.3248$

The PCRI4 model focuses on the relationship between process innovation and *external-domestic R&D intensity*, which is shown in Table 94. Because the Wald test and 5 of 6 individual z-statistics (not shown here) are not statistically significant, the PCRI4 model is not shown here. Hence, the null hypothesis, $H4c_0$, could not be tested for manufacture of other non-metallic mineral products.

Regression results of PDRI5 and PCRI5 models include coefficient, p-value, and average marginal effect, which are shown in Table 95. These models analyze the effect of *external-foreign R&D intensity* on the probability of product and process innovations, respectively.

The PDRI5 model focuses on the relationship between product innovation and *external-foreign R&D intensity*, which is shown in Table 95. In this model, independent variables are not statistically significant at 10% level. Hence, the null hypothesis, $H2d_0$, is not rejected.

The PCRI5 model focuses on the relationship between process innovation and *external-foreign R&D intensity*, which is shown in Table 95. Because convergence not achieved during the analysis and because the Wald test and all individual z-statistics (not shown here) are not statistically significant, the PCRI5 model is not shown here. Hence, the null hypothesis, $H4d_0$, could not be tested for manufacture of other non-metallic mineral products.

Table 95: Regression Results of PDRI5 and PCRI5 Models – C-23

Variable Name	PDRI5			PCRI5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extfrgrdint</i>	2558.74	0.502	876.63			
<i>rdperint</i>	0.2218	0.498	0.0760			
<i>IntoverD</i>	-0.0373	0.687	-0.0128			
<i>HHI</i>	-99.829	0.888	-34.202			
<i>phd_ma</i>	-0.0052	0.910	-0.0018			
<i>ipicsec</i>	-0.0017	0.947	-0.0006			

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI5: Wald chi2(6)=13.67 Prob > chi2=0.0335

For PCRI5: Wald chi2(6)=5.92 Prob > chi2=0.4321 (Convergence not achieved)

According to the analysis of the manufacture of other non-metallic mineral products, there are many findings in terms of product innovation. These are:

- R&D expenditure variables except total and internal are not statistically significant at 10% level and have positive effect on the likelihood of occurrence of product innovation in Turkish manufacturing industry. The most effective one is *total R&D expenditure*.
- Only *external-domestic R&D intensity* variable is statistically significant and has positive effect on the likelihood of occurrence of product innovation in Turkish manufacturing industry.
- The other independent variables are interpreted by focusing on the PDRE1 and PDRI1 models. Because these models cover *total R&D expenditures*. According to the PDRE1 model, *turnover* is statistically significant and has negative effect on the likelihood of occurrence of product innovation. It means that more *turnover* decreases the likelihood of occurrence of product

innovation in the manufacture of other non-metallic mineral products. The PDRI1 model is not statistically significant according to the Wald test.

According to the analysis of the manufacture of other non-metallic mineral products, there are many findings in terms of process innovation. These are:

- R&D expenditure variables such as total and internal (PCRE1 and PCRE2) are statistically significant and have positive effect on the likelihood of occurrence of process innovation. The most effective one is *total R&D expenditure*.
- All R&D intensity variables are not statistically significant at 10% level. The result of PCRI5 model is not calculated because of nonachievement of convergence.
- The other independent variables are interpreted by focusing on the PCRE1 and PCRI1 models. Because these models cover *total R&D expenditures*. According to the PCRE1 model, *turnover* is statistically significant and has negative effect on the likelihood of occurrence of process innovation. It means that more *turnover* decreases the likelihood of occurrence of process innovation in the manufacture of other non-metallic mineral products. The PCRI1 model is not statistically significant according to the Wald test.

Results of the analyses are also viewed by comparing product and process innovation in terms of the manufacture of other non-metallic mineral products. These are:

- The impact of *total* and *internal R&D expenditures* on the likelihood of occurrence of product innovation is greater than its impact on the likelihood of occurrence of process innovation.
- *External-domestic R&D intensity* affects only the likelihood of occurrence of product innovation positively.

4.2.2.7. Manufacture of Basic Metals, C-24 by NACE Rev. 2

Firms that are engaged in R&D in manufacture of basic metals are analyzed with twenty models such as 10 product innovation models and 10 process innovation models.

Regression results of PDRE1 and PCRE1 models include coefficient, p-value, and average marginal effect, which are shown in Table 96. These models analyze the effect of *total R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE1 model focuses on the relationship between product innovation and *total R&D expenditure*, which is shown in Table 96. In this model, independent variables except *total R&D expenditure* and *R&D personnel intensity* are not statistically significant at 10% level. *Total R&D expenditure* and *R&D personnel intensity* are statistically significant at 1% level. Hence, the null hypothesis, $H1_0$, is rejected. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *total R&D expenditure*, on average, leads to an increase of 7.59 percent in the likelihood of occurrence of product innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to a decrease of 1.88 in the likelihood of occurrence of product innovation.

Table 96: Regression Results of PDRE1 and PCRE1 Models – C-24

Variable Name	PDRE1			PCRE1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntrdexpD</i>	0.2037	0.006 ***	0.0759	0.2046	0.061 **	0.0665
<i>rdperint</i>	-5.0332	0.005 ***	-1.8765	-4.6075	0.097 *	-1.4964
<i>IntoverD</i>	-0.0124	0.894	-0.0046	-0.0349	0.694	-0.0113
<i>HHI</i>	-119.10	0.121	-44.404	-155.94	0.113	-50.645
<i>phd_ma</i>	-0.0002	0.990	-0.0001	0.0083	0.733	0.0027
<i>ipicsec</i>	-0.0022	0.704	-0.0008	-0.0159	0.082 *	-0.0052

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE1: Wald chi2(6)=20.94 Prob > chi2=0.0019

For PCRE1: Wald chi2(6)=11.23 Prob > chi2=0.0815

The PCRE1 model focuses on the relationship between process innovation and *total R&D expenditure*, which is shown in Table 96. In this model, independent variables except *total R&D expenditure*, *R&D personnel intensity*, and *industrial production index by manufacturing industry* are not statistically significant at 10% level. *Total R&D expenditure* is statistically significant at 5% level, *R&D personnel intensity* and *industrial production index by manufacturing industry* are statistically significant at 10% level. Hence, the null hypothesis, $H3_0$, is rejected. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *total R&D expenditure*, on average, leads to an increase of 6.65 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to a decrease of 1.5 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to a decrease of 0.52 percent in the likelihood of occurrence of process innovation.

Regression results of PDRE2 and PCRE2 models include coefficient, p-value, and average marginal effect, which are shown in Table 97. These models analyze the effect of *internal R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE2 model focuses on the relationship between product innovation and *internal R&D expenditure*, which is shown in Table 97. In this model, independent variables except *internal R&D expenditure* and *R&D personnel intensity* are not statistically significant at 10% level. *Internal R&D expenditure* and *R&D personnel intensity* are statistically significant at 1% level. Hence, the null hypothesis, $H1a_0$, is rejected. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *internal R&D expenditure*, on average, leads to an increase of 7.9 percent in the likelihood of occurrence of product innovation.

- A unit increase in the value of *R&D personnel intensity*, on average, leads to a decrease of 1.96 in the likelihood of occurrence of product innovation.

The PCRE2 model focuses on the relationship between process innovation and *internal R&D expenditure*, which is shown in Table 97. In this model, *internal R&D expenditure*, *R&D personnel intensity*, and *industrial production index by manufacturing industry* are statistically significant at 10% level. Hence, the null hypothesis, $H3a_0$, is rejected. The rest of the independent variables are not statistically significant at 10% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *internal R&D expenditure*, on average, leads to an increase of 6.38 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to a decrease of 1.51 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to a decrease of 0.49 percent in the likelihood of occurrence of process innovation.

Table 97: Regression Results of PDRE2 and PCRE2 Models – C-24

Variable Name	PDRE2			PCRE2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntintrdexpD</i>	0.2125	0.005 ***	0.0790	0.1959	0.074 *	0.0638
<i>rdperint</i>	-5.2798	0.004 ***	-1.9640	-4.6468	0.095 *	-1.5124
<i>IntoverD</i>	-0.0177	0.849	-0.0066	-0.0330	0.711	-0.0108
<i>HHI</i>	-113.54	0.133	-42.234	-149.70	0.127	-48.724
<i>phd_ma</i>	-0.0013	0.935	-0.0005	0.0097	0.691	0.0032
<i>ipicsec</i>	-0.0018	0.746	-0.0007	-0.0152	0.093 *	-0.0049

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE2: Wald $\chi^2(6) = 21.51$ Prob > $\chi^2 = 0.0015$

For PCRE2: Wald $\chi^2(6) = 11.07$ Prob > $\chi^2 = 0.0861$

Regression results of PDRE3 and PCRE3 models include coefficient, p-value, and average marginal effect, which are shown in Table 98. These models analyze the effect of *external R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE3 model focuses on the relationship between product innovation and *external R&D expenditure*, which is shown in Table 98. In this model, *R&D personnel intensity* and the *number of highly educated R&D personnel* are statistically significant at 5% level. The rest of the independent variables are not statistically significant at 10% level. Hence, the null hypothesis, $H1b_0$, is rejected. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to a decrease of 1.23 in the likelihood of occurrence of product innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.014 in the likelihood of occurrence of product innovation.

The PCRE3 model focuses on the relationship between process innovation and *external R&D expenditure*, which is shown in Table 98. Because the Wald test and 5 of 6 individual z-statistics (not shown here) are not statistically significant, the PCRE3 model is not shown here. Hence, the null hypothesis, $H3b_0$, could not be tested for manufacture of basic metals.

Table 98: Regression Results of PDRE3 and PCRE3 Models – C-24

Variable Name	PDRE3			PCRE3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpD</i>	-0.0310	0.257	-0.0118			
<i>rdperint</i>	-3.2445	0.039 **	-1.2325			
<i>IntoverD</i>	0.0677	0.430	0.0257			
<i>HHI</i>	-59.821	0.447	-22.724			
<i>phd_ma</i>	0.0368	0.013 **	0.0140			
<i>ipicsec</i>	0.0022	0.719	0.0008			

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE3: Wald $\chi^2(6)=17.53$ Prob > $\chi^2=0.0075$

For PCRE3: Wald $\chi^2(6)=10.13$ Prob > $\chi^2=0.1194$

Regression results of PDRE4 and PCRE4 models include coefficient, p-value, and average marginal effect, which are shown in Table 99. These models analyze the effect of *external-domestic R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE4 model focuses on the relationship between product innovation and *external-domestic R&D expenditure*, which is shown in Table 99. In this model, *R&D personnel intensity* and the *number of highly educated R&D personnel* are statistically significant at 5% level. The rest of the independent variables are not statistically significant at 10% level. Hence, the null hypothesis, $H1c_0$, is not rejected. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to a decrease of 1.27 in the likelihood of occurrence of product innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.015 in the likelihood of occurrence of product innovation.

Table 99: Regression Results of PDRE4 and PCRE4 Models – C-24

Variable Name	PDRE4			PCRE4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpdomD</i>	-0.0369	0.244	-0.0140			
<i>rdperint</i>	-3.3412	0.034 **	-1.2669			
<i>IntoverD</i>	0.0631	0.459	0.0239			
<i>HHI</i>	-55.927	0.483	-21.206			
<i>phd_ma</i>	0.0384	0.014 **	0.0146			
<i>ipicsec</i>	0.0024	0.698	0.0009			

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE4: Wald $\chi^2(6)=17.31$ Prob > $\chi^2=0.0082$

For PCRE4: Wald $\chi^2(6)=10.59$ Prob > $\chi^2=0.1018$

The PCRE4 model focuses on the relationship between process innovation and *external-domestic R&D expenditure*, which is shown in Table 99. Because the Wald test and 5 of 6 individual z-statistics (not shown here) are not statistically significant, the PCRE4 model is not shown here. Hence, the null hypothesis, $H3c_0$, could not be tested for manufacture of basic metals.

Regression results of PDRE5 and PCRE5 models include coefficient, p-value, and average marginal effect, which are shown in Table 100. These models analyze the effect of *external-foreign R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE5 model focuses on the relationship between product innovation and *external-foreign R&D expenditure*, which is shown in Table 100. In this model, *R&D personnel intensity* and the *number of highly educated R&D personnel* are statistically significant at 10% and 5% level, respectively. The rest of the independent variables are not statistically significant at 10% level. Hence, the null hypothesis, $H1d_0$, is not rejected. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to a decrease of 1.16 in the likelihood of occurrence of product innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.011 in the likelihood of occurrence of product innovation.

Table 100: Regression Results of PDRE5 and PCRE5 Models – C-24

Variable Name	PDRE5			PCRE5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpforD</i>	0.0083	0.404	0.0032			
<i>rdperint</i>	-3.0398	0.062 *	-1.1589			
<i>IntoverD</i>	0.0711	0.410	0.0271			
<i>HHI</i>	-94.938	0.200	-36.194			
<i>phd_ma</i>	0.0291	0.039 **	0.0111			
<i>ipicsec</i>	0.0008	0.888	0.0003			

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE5: Wald $\chi^2(6) = 17.23$ Prob > $\chi^2 = 0.0085$

For PCRE5: Wald $\chi^2(6) = 9.21$ Prob > $\chi^2 = 0.1619$

The PCRE5 model focuses on the relationship between process innovation and *external-domestic R&D expenditure*, which is shown in Table 100. Because the Wald test and 5 of 6 individual z-statistics (not shown here) are not statistically significant, the PCRE5 model is not shown here. Hence, the null hypothesis, $H3d_0$, could not be tested for manufacture of basic metals.

Regression results of PDRI1 and PCRI1 models include coefficient, p-value, and average marginal effect, which are shown in Table 101. These models analyze the effect of *total R&D intensity* on the probability of product and process innovations, respectively.

The PDRI1 model focuses on the relationship between product innovation and *total R&D intensity*, which is shown in Table 101. In this model, *total RD intensity*, *R&D personnel intensity*, and the *number of highly educated R&D personnel* are statistically significant at 5%, 5%, and 10% level, respectively. Hence, the null hypothesis, H_{20} , is rejected. The rest of the independent variables are not statistically significant at 10% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *total R&D intensity*, on average, leads to an increase of 8.37 in the likelihood of occurrence of product innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to a decrease of 1.86 in the likelihood of occurrence of product innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.011 in the likelihood of occurrence of product innovation.

The PCRI1 model focuses on the relationship between process innovation and *total R&D intensity*, which is shown in Table 101. Because the Wald test and 5 of 6 individual z-statistics (not shown here) are not statistically significant, the PCRI1 model is not shown here. Hence, the null hypothesis, H_{40} , could not be tested for manufacture of basic metals.

Table 101: Regression Results of PDRI1 and PCRI1 Models – C-24

Variable Name	PDRI1			PCRI1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>totrdint</i>	22.275	0.014 **	8.3717			
<i>rdperint</i>	-4.9406	0.012 **	-1.8568			
<i>lntoverD</i>	0.1227	0.200	0.0461			
<i>HHI</i>	-98.855	0.193	-37.153			
<i>phd_ma</i>	0.0240	0.079 *	0.0090			
<i>ipicsec</i>	-0.0007	0.904	-0.0003			

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI1: Wald $\chi^2(6)=18.90$ Prob > $\chi^2=0.0043$

For PCRI1: Wald $\chi^2(6)=8.82$ Prob > $\chi^2=0.1841$

Regression results of PDRI2 and PCRI2 models include coefficient, p-value, and average marginal effect, which are shown in Table 102. These models analyze the

effect of *internal R&D intensity* on the probability of product and process innovations, respectively.

The PDRI2 model focuses on the relationship between product innovation and *internal R&D intensity*, which is shown in Table 102. In this model, internal RD intensity, *R&D personnel intensity*, and the *number of highly educated R&D personnel* are statistically significant at 5%, 5%, and 10% level, respectively. Hence, the null hypothesis, $H2a_0$, is rejected. The rest of the independent variables are not statistically significant at 10% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *total R&D intensity*, on average, leads to an increase of 8.71 in the likelihood of occurrence of product innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to a decrease of 1.93 in the likelihood of occurrence of product innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.009 in the likelihood of occurrence of product innovation.

Table 102: Regression Results of PDRI2 and PCRI2 Models – C-24

Variable Name	PDRI2			PCRI2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>intrdint</i>	23.211	0.011 **	8.7095			
<i>rdperint</i>	-5.1352	0.010 **	-1.9269			
<i>lntoverD</i>	0.1235	0.197	0.0463			
<i>HHI</i>	-94.618	0.209	-35.503			
<i>phd_ma</i>	0.0240	0.079 *	0.0090			
<i>ipicsec</i>	-0.0005	0.937	-0.0002			

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI2: Wald $\chi^2(6)=19.37$ Prob > $\chi^2=0.0036$

For PCRI2: Wald $\chi^2(6)=8.93$ Prob > $\chi^2=0.1774$

The PCRI2 model focuses on the relationship between process innovation and *internal R&D intensity*, which is shown in Table 102. Because the Wald test and 5 of 6 individual z-statistics (not shown here) are not statistically significant, the PCRI2 model is not shown here. Hence, the null hypothesis, $H4a_0$, could not be tested for manufacture of basic metals.

Regression results of PDRI3 and PCRI3 models include coefficient, p-value, and average marginal effect, which are shown in Table 103. These models analyze the effect of *external R&D intensity* on the probability of product and process innovations, respectively.

The PDRI3 model focuses on the relationship between product innovation and *external R&D intensity*, which is shown in Table 103. In this model, *R&D personnel intensity* and the *number of highly educated R&D personnel* are statistically significant at 10% and 5% level, respectively. Hence, the null hypothesis, $H2b_0$, is not rejected. The rest of the independent variables are not statistically significant at 10% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to a decrease of 1.18 in the likelihood of occurrence of product innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.011 in the likelihood of occurrence of product innovation.

The PCRI3 model focuses on the relationship between process innovation and *external R&D intensity*, which is shown in Table 103. In this model, *external RD intensity*, *HHI*, and the *number of highly educated R&D personnel* are statistically significant at 5%, 10%, and 5% level, respectively. Hence, the null hypothesis, $H4b_0$, is rejected. The rest of the independent variables are not statistically significant at 10% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external R&D intensity*, on average, leads to an increase of 32.41 in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to a decrease of 60.82 in the likelihood of occurrence of process innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.015 in the likelihood of occurrence of process innovation.

Table 103: Regression Results of PDRI3 and PCRI3 Models – C-24

Variable Name	PDRI3			PCRI3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extrdint</i>	-20.599	0.352	-7.8560	98.308	0.019 **	32.406
<i>rdperint</i>	-3.0860	0.057 *	-1.1769	-3.1167	0.190	-1.0274
<i>IntoverD</i>	0.0707	0.411	0.0270	0.0571	0.470	0.0188
<i>HHI</i>	-89.450	0.234	-34.114	-184.52	0.080 *	-60.824
<i>phd_ma</i>	0.0298	0.027 **	0.0114	0.0449	0.047 **	0.0148
<i>ipicsec</i>	0.0012	0.841	0.0004	-0.0138	0.130	-0.0045

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI3: Wald chi2(6)=17.27 Prob > chi2=0.0084

For PCRI3: Wald chi2(6)=13.27 Prob > chi2=0.0390

Regression results of PDRI4 and PCRI4 models include coefficient, p-value, and average marginal effect, which are shown in Table 104. These models analyze the effect of *external-domestic R&D intensity* on the probability of product and process innovations, respectively.

The PDRI4 model focuses on the relationship between product innovation and *external-domestic R&D intensity*, which is shown in Table 104. In this model, external-domestic RD intensity, *R&D personnel intensity*, and the *number of highly educated R&D personnel* are statistically significant at 5% level. Hence, the null hypothesis, $H2c_0$, is rejected. The rest of the independent variables are not statistically significant at 10% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external-domestic R&D intensity*, on average, leads to a decrease of 23.35 in the likelihood of occurrence of product innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to a decrease of 1.23 in the likelihood of occurrence of product innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.012 in the likelihood of occurrence of product innovation.

The PCRI4 model focuses on the relationship between process innovation and *external-domestic R&D intensity*, which is shown in Table 104. In this model,

external-domestic RD intensity, *HHI*, and the *number of highly educated R&D personnel* are statistically significant at 10%, 10%, and 5% level, respectively. Hence, the null hypothesis, $H4c_0$, is rejected. The rest of the independent variables are not statistically significant at 10% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external-domestic R&D intensity*, on average, leads to an increase of 34.43 in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to a decrease of 60.27 in the likelihood of occurrence of process innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.015 in the likelihood of occurrence of process innovation.

Table 104: Regression Results of PDRI4 and PCRI4 Models – C-24

Variable Name	PDRI4			PCRI4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extdomrdint</i>	-61.354	0.013 **	-23.354	104.26	0.093 *	34.430
<i>rdperint</i>	-3.2272	0.049 **	-1.2284	-3.1070	0.193	-1.0260
<i>IntoverD</i>	0.0679	0.430	0.0258	0.0581	0.464	0.0192
<i>HHI</i>	-84.775	0.261	-32.269	-182.51	0.083 *	-60.268
<i>phd_ma</i>	0.0308	0.023 **	0.0117	0.0438	0.049 **	0.0145
<i>ipicsec</i>	0.0015	0.790	0.0006	-0.0137	0.132	-0.0045

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI4: Wald $\chi^2(6) = 25.22$ Prob > $\chi^2 = 0.0003$

For PCRI4: Wald $\chi^2(6) = 11.42$ Prob > $\chi^2 = 0.0763$

Regression results of PDRI5 and PCRI5 models include coefficient, p-value, and average marginal effect, which are shown in Table 104. These models analyze the effect of *external-foreign R&D intensity* on the probability of product and process innovations, respectively.

The PDRI5 model focuses on the relationship between product innovation and *external-foreign R&D intensity*, which is shown in Table 105. In this model, *external-foreign RD intensity*, *R&D personnel intensity*, and the *number of highly educated R&D personnel* are statistically significant at 1% and 10% level, respectively. Hence,

the null hypothesis, $H2d_0$, is rejected. The rest of the independent variables are not statistically significant at 10% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external-foreign R&D intensity*, on average, leads to an increase of 13.27 in the likelihood of occurrence of product innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to a decrease of 1.16 in the likelihood of occurrence of product innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.012 in the likelihood of occurrence of product innovation.

Table 105: Regression Results of PDRI5 and PCRI5 Models – C-24

Variable Name	PDRI5			PCRI5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extfrgrdint</i>	34.767	0.000 ***	13.266	80.301	0.000 ***	26.555
<i>rdperint</i>	-3.0320	0.063 *	-1.1569	-3.3281	0.162	-1.1006
<i>IntoverD</i>	0.0708	0.412	0.0270	0.0513	0.515	0.0170
<i>HHI</i>	-94.515	0.202	-36.064	-168.77	0.105	-55.811
<i>phd_ma</i>	0.0301	0.027 *	0.0115	0.0452	0.045 **	0.0150
<i>ipicsec</i>	0.0008	0.888	0.0003	-0.0125	0.162	-0.0041

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI5: Wald $\chi^2(6)=28.66$ Prob > $\chi^2=0.0001$

For PCRI5: Wald $\chi^2(6)=96.15$ Prob > $\chi^2=0.0000$

The PCRI5 model focuses on the relationship between process innovation and *external-foreign R&D intensity*, which is shown in Table 105. In this model, *external-foreign RD intensity* and the *number of highly educated R&D personnel* are statistically significant at 1% and 5% level, respectively. Hence, the null hypothesis, $H4d_0$, is rejected. The rest of the independent variables are not statistically significant at 10% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external-foreign R&D intensity*, on average, leads to an increase of 26.56 in the likelihood of occurrence of process innovation.

- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.015 in the likelihood of occurrence of process innovation.

According to the analysis of the manufacture of basic metals, there are many findings in terms of product innovation. These are:

- R&D expenditure variables except total and internal are not statistically significant at 10% level and have positive effect on the likelihood of occurrence of product innovation in Turkish manufacturing industry. The most effective one is *internal R&D expenditure*.
- R&D intensity variables except external are statistically significant but only external-domestic one has negative effect on the likelihood of occurrence of product innovation in Turkish manufacturing industry. The others have positive effects on it. The most effective one is *external-foreign R&D intensity*.
- The other independent variables are interpreted by focusing on the PDRE1 and PDRI1 models. Because these models cover *total R&D expenditures*. According to the PDRE1 model, only *R&D personnel intensity* is statistically significant and has negative effect on the likelihood of occurrence of product innovation. According to the PDRI1 model, *R&D personnel intensity* and the *number of highly educated R&D personnel* are statistically significant and have negative and positive effects respectively on the likelihood of occurrence of product innovation. It means that more *R&D personnel intensity* decreases the likelihood of occurrence of product innovation, and more highly educated R&D personnel increases in the manufacture of basic metals.

According to the analysis of the manufacture of basic metals, there are many findings in terms of process innovation. These are:

- R&D expenditure variables such as total and internal are statistically significant and have positive effect on the likelihood of occurrence of

process innovation. The most effective one is *total R&D expenditure*. PCRE3, PCRE4, and PCRE5 models are not according to the Wald test.

- R&D intensity variables except total and internal are statistically significant and have positive effect on the likelihood of occurrence of process innovation. The most effective one is *external-domestic R&D intensity*.
- The other independent variables are interpreted by focusing on the PCRE1 and PCRI1 models. Because these models cover *total R&D expenditures*. According to the PCRE1 model, *R&D personnel intensity* and *industrial production index by manufacturing industry* are statistically significant but they have negative effect on the likelihood of occurrence of process innovation. It means that more *R&D personnel intensity* and *industrial production index by manufacturing industry* decrease the likelihood of occurrence of process innovation in the manufacture of basic metals. PCRI1 model is not statistically significant according to the Wald test.

Results of the analyses are also viewed by comparing product and process innovation in terms of manufacture of basic metals. These are:

- The impact of *total* and *internal R&D expenditure* on the likelihood of occurrence of product innovation is greater than its impact on the likelihood of occurrence of process innovation.
- *Total* and *internal R&D intensity* affect only the likelihood of occurrence of product innovation positively.
- *External R&D intensity* affects only the likelihood of occurrence of process innovation positively.
- The impact of *external-domestic* and *external-foreign R&D intensity* on the likelihood of occurrence of process innovation is greater than its impact on the likelihood of occurrence of product innovation.

4.2.2.8. Manufacture of Fabricated Metal Products, except Machinery and Equipment, C-25 by NACE Rev. 2

Firms that are engaged in R&D in manufacture of fabricated metal products, except machinery and equipment, are analyzed with twenty models such as 10 product innovation models and 10 process innovation models.

Regression results of PDRE1 and PCRE1 models include coefficient, p-value, and average marginal effect, which are shown in Table 106. These models analyze the effect of *total R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE1 model focuses on the relationship between product innovation and *total R&D expenditure*, which is shown in Table 106. In this model, independent variables except *total R&D expenditure* and the *number of highly educated R&D personnel* are not statistically significant at 10% level. *Total R&D expenditure* and the *number of highly educated R&D personnel* are statistically significant at 5% and 10% level, respectively. Hence, the null hypothesis, $H1_0$, is rejected. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *total R&D expenditure*, on average, leads to an increase of 4.85 percent in the likelihood of occurrence of product innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.033 in the likelihood of occurrence of product innovation.

The PCRE1 model focuses on the relationship between process innovation and *total R&D expenditure*, which is shown in Table 106. In this model, independent variables except the *number of highly educated R&D personnel* are not statistically significant at 10% level. Hence, the null hypothesis, $H3_0$, is not rejected. The *number of highly educated R&D personnel* is statistically significant at the 10% level. It means that a unit increase in the value of the *number of highly educated R&D personnel*, on

average, leads to an increase of 0.027 in the likelihood of occurrence of process innovation.

Table 106: Regression Results of PDRE1 and PCRE1 Models – C-25

Variable Name	PDRE1			PCRE1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntrdexpD</i>	0.1508	0.030 **	0.0485	0.1105	0.125	0.0339
<i>rdperint</i>	-1.6408	0.290	-0.5277	-0.2401	0.842	-0.0736
<i>IntoverD</i>	-0.0645	0.583	-0.0207	0.0306	0.779	0.0094
<i>HHI</i>	-189.23	0.824	-60.862	-206.26	0.803	-63.204
<i>phd_ma</i>	0.1017	0.076 *	0.0327	0.0864	0.052 *	0.0265
<i>ipicsec</i>	-0.0040	0.570	-0.0013	-0.0023	0.726	-0.0007

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE1: Wald chi2(6)=17.92 Prob > chi2=0.0064

For PCRE1: Wald chi2(6)=11.22 Prob > chi2=0.0819

Regression results of PDRE2 and PCRE2 models include coefficient, p-value, and average marginal effect, which are shown in Table 107. These models analyze the effect of *internal R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE2 model focuses on the relationship between product innovation and *internal R&D expenditure*, which is shown in Table 107. In this model, independent variables except *internal R&D expenditure* and the *number of highly educated R&D personnel* are not statistically significant at 10% level. *Internal R&D expenditure* and the *number of highly educated R&D personnel* are statistically significant at 5% and 10% level, respectively. Hence, the null hypothesis, $H1a_0$, is rejected. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *total R&D expenditure*, on average, leads to an increase of 4.5 percent in the likelihood of occurrence of product innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.033 in the likelihood of occurrence of product innovation.

The PCRE2 model focuses on the relationship between process innovation and *internal R&D expenditure*, which is shown in Table 107. In this model, independent

variables except the *number of highly educated R&D personnel* are not statistically significant at 10% level. Hence, the null hypothesis, $H3a_0$, is not rejected. The *number of highly educated R&D personnel* is statistically significant at the 10% level. It means that a unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.027 in the likelihood of occurrence of process innovation.

Table 107: Regression Results of PDRE2 and PCRE2 Models – C-25

Variable Name	PDRE2			PCRE2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntintrdexpD</i>	0.1397	0.042 **	0.0450	0.1015	0.157	0.0311
<i>rdperint</i>	-1.5523	0.316	-0.5003	-0.1680	0.889	-0.0515
<i>IntoverD</i>	-0.0562	0.630	-0.0181	0.0376	0.729	0.0115
<i>HHI</i>	-189.44	0.824	-61.052	-211.47	0.798	-64.825
<i>phd_ma</i>	0.1035	0.069 *	0.0334	0.0885	0.050 *	0.0271
<i>ipicsec</i>	-0.0040	0.575	-0.0013	-0.0023	0.726	-0.0007

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE2: Wald $\chi^2(6)=16.92$ Prob > $\chi^2=0.0096$

For PCRE2: Wald $\chi^2(6)=10.96$ Prob > $\chi^2=0.0897$

Regression results of PDRE3 and PCRE3 models include coefficient, p-value, and average marginal effect, which are shown in Table 108. These models analyze the effect of *external R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE3 model focuses on the relationship between product innovation and *external R&D expenditure*, which is shown in Table 108. In this model, independent variables except the *number of highly educated R&D personnel* are not statistically significant at 10% level. Hence, the null hypothesis, $H1b_0$, is not rejected. The *number of highly educated R&D personnel* are statistically significant at 5% level. It means that a unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.04 in the likelihood of occurrence of product innovation.

The PCRE3 model focuses on the relationship between process innovation and *external R&D expenditure*, which is shown in Table 108. In this model, independent variables except the *number of highly educated R&D personnel* are not statistically significant at 10% level. Hence, the null hypothesis, $H3b_0$, is not rejected. The *number*

of highly educated R&D personnel is statistically significant at the 5% level. It means that a unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.033 in the likelihood of occurrence of process innovation.

Table 108: Regression Results of PDRE3 and PCRE3 Models – C-25

Variable Name	PDRE3			PCRE3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpD</i>	0.0246	0.131	0.0080	0.0049	0.769	0.0015
<i>rdperint</i>	-0.5013	0.702	-0.1630	0.5787	0.591	0.1787
<i>IntoverD</i>	0.0363	0.698	0.0118	0.1048	0.217	0.0324
<i>HHI</i>	-66.860	0.939	-21.747	-118.08	0.887	-36.458
<i>phd_ma</i>	0.1226	0.028 **	0.0399	0.1077	0.030 **	0.0333
<i>ipicsec</i>	-0.0026	0.725	-0.0008	-0.0014	0.830	-0.0004

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE3: Wald chi2(6)=16.07 Prob > chi2=0.0134

For PCRE3: Wald chi2(6)=12.11 Prob > chi2=0.0596

Regression results of PDRE4 and PCRE4 models include coefficient, p-value, and average marginal effect, which are shown in Table 109. These models analyze the effect of *external-domestic R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE4 model focuses on the relationship between product innovation and *external-domestic R&D expenditure*, which is shown in Table 109. In this model, independent variables except *external-domestic R&D expenditure* and the *number of highly educated R&D personnel* are not statistically significant at 10% level. *External-domestic R&D expenditure* and the *number of highly educated R&D personnel* are statistically significant at 10% and 5% level, respectively. Hence, the null hypothesis, $H1c_0$, is rejected. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *external-domestic R&D expenditure*, on average, leads to an increase of 1.16 percent in the likelihood of occurrence of product innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.033 in the likelihood of occurrence of product innovation.

The PCRE4 model focuses on the relationship between process innovation and *external-domestic R&D expenditure*, which is shown in Table 109. Because the Wald test and 5 of 6 individual z-statistics (not shown here) are not statistically significant, the PCRE4 model is not shown here. Hence, the null hypothesis, $H3ca_0$, could not be tested for manufacture of fabricated metal products, except machinery and equipment.

Table 109: Regression Results of PDRE4 and PCRE4 Models – C-25

Variable Name	PDRE4			PCRE4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpdomD</i>	0.0358	0.050 *	0.0116			
<i>rdperint</i>	-0.4709	0.719	-0.1528			
<i>IntoverD</i>	0.0380	0.684	0.0123			
<i>HHI</i>	-58.132	0.946	-18.864			
<i>phd_ma</i>	0.1174	0.033 **	0.0381			
<i>ipicsec</i>	-0.0025	0.727	-0.0008			

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE4: Wald $\chi^2(6)=15.83$ Prob > $\chi^2=0.0147$

For PCRE4: Wald $\chi^2(6)=9.98$ Prob > $\chi^2=0.1253$

Regression results of PDRE5 and PCRE5 models include coefficient, p-value, and average marginal effect, which are shown in Table 110. These models analyze the effect of *external-foreign R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE5 model focuses on the relationship between product innovation and *external-foreign R&D expenditure*, which is shown in Table 110. In this model, independent variables except the *number of highly educated R&D personnel* are not statistically significant at 10% level. Hence, the null hypothesis, $H1d_0$, is not rejected. The *number of highly educated R&D personnel* are statistically significant at 5% level. It means that a unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.041 in the likelihood of occurrence of product innovation.

The PCRE5 model focuses on the relationship between process innovation and *external-domestic R&D expenditure*, which is shown in Table 110. In this model, independent variables except the *number of highly educated R&D personnel* are not statistically significant at 10% level. Hence, the null hypothesis, $H3d_0$, is not rejected. The *number of highly educated R&D personnel* is statistically significant at the 5%

level. It means that a unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.033 in the likelihood of occurrence of process innovation.

Table 110: Regression Results of PDRE5 and PCRE5 Models – C-25

Variable Name	PDRE5			PCRE5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpforD</i>	-0.0308	0.355	-0.0101	-0.0508	0.210	-0.0156
<i>rdperint</i>	-0.4242	0.750	-0.1386	0.6987	0.517	0.2151
<i>IntoverD</i>	0.0451	0.636	0.0147	0.1177	0.163	0.0363
<i>HHI</i>	-49.025	0.956	-16.024	-184.17	0.826	-56.710
<i>phd_ma</i>	0.1251	0.016 **	0.0409	0.1068	0.018 **	0.0329
<i>ipicsec</i>	-0.0027	0.717	-0.0009	-0.0019	0.770	-0.0006

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE5: Wald chi2(6)=11.06 Prob > chi2=0.0865

For PCRE5: Wald chi2(6)=26.30 Prob > chi2=0.0002

Regression results of PDRI1 and PCRI1 models include coefficient, p-value, and average marginal effect, which are shown in Table 111. These models analyze the effect of *total R&D intensity* on the probability of product and process innovations, respectively.

The PDRI1 model focuses on the relationship between product innovation and *total R&D intensity*, which is shown in Table 111. In this model, *total R&D intensity* and the *number of highly educated R&D personnel* are statistically significant at 10% and 5% level, respectively. Hence, the null hypothesis, H_{20} , is rejected. The rest of the independent variables are not statistically significant at 10% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *total R&D intensity*, on average, leads to an increase of 8.36 in the likelihood of occurrence of product innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.039 in the likelihood of occurrence of product innovation.

The PCRI1 model focuses on the relationship between process innovation and *total R&D intensity*, which is shown in Table 111. Because the Wald test and 5 of 6 individual z-statistics (not shown here) are not statistically significant, the PCRI1

model is not shown here. Hence, the null hypothesis, $H4_0$, could not be tested for manufacture of fabricated metal products, except machinery and equipment.

Table 111: Regression Results of PDR11 and PCRI1 Models – C-25

Variable Name	PDR11			PCRI1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>totrdint</i>	2.5862	0.063 *	0.8359			
<i>rdperint</i>	-1.5767	0.294	-0.5096			
<i>lntoverD</i>	0.0661	0.494	0.0214			
<i>HHI</i>	-143.10	0.869	-46.252			
<i>phd_ma</i>	0.1215	0.031 **	0.0393			
<i>ipicsec</i>	-0.0033	0.649	-0.0011			

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDR11: Wald $\chi^2(6) = 15.68$ Prob > $\chi^2 = 0.0156$

For PCRI1: Wald $\chi^2(6) = 9.93$ Prob > $\chi^2 = 0.1277$

Regression results of PDR12 and PCRI2 models include coefficient, p-value, and average marginal effect, which are shown in Table 112. These models analyze the effect of *internal R&D intensity* on the probability of product and process innovations, respectively.

The PDR12 model focuses on the relationship between product innovation and *internal R&D intensity*, which is shown in Table 112. In this model, *internal R&D intensity* and the *number of highly educated R&D personnel* are statistically significant at 10% and 5% level, respectively. Hence, the null hypothesis, $H2a_0$, is rejected. The rest of the independent variables are not statistically significant at 10% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *internal R&D intensity*, on average, leads to an increase of 7.75 in the likelihood of occurrence of product innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.039 in the likelihood of occurrence of product innovation.

The PCRI2 model focuses on the relationship between process innovation and *internal R&D intensity*, which is shown in Table 112. Because the Wald test and 5 of 6 individual z-statistics (not shown here) are not statistically significant, the PCRI2

model is not shown here. Hence, the null hypothesis, $H4a_0$, could not be tested for manufacture of fabricated metal products, except machinery and equipment.

Table 112: Regression Results of PDRI2 and PCRI2 Models – C-25

Variable Name	PDRI2			PCRI2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>intrdint</i>	2.3935	0.073 *	0.7745			
<i>rdperint</i>	-1.4831	0.320	-0.4799			
<i>IntoverD</i>	0.0646	0.503	0.0209			
<i>HHI</i>	-143.85	0.869	-46.548			
<i>phd_ma</i>	0.1217	0.030 **	0.0394			
<i>ipicsec</i>	-0.0033	0.651	-0.0011			

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI2: Wald $\chi^2(6)=15.1$ Prob > $\chi^2=0.0194$

For PCRI2: Wald $\chi^2(6)=10.01$ Prob > $\chi^2=0.1241$

Regression results of PDRI3 and PCRI3 models include coefficient, p-value, and average marginal effect, which are shown in Table 113. These models analyze the effect of *external R&D intensity* on the probability of product and process innovations, respectively.

The PDRI3 model focuses on the relationship between product innovation and *external R&D intensity*, which is shown in Table 113. In this model, *external R&D intensity* and the *number of highly educated R&D personnel* are statistically significant at 5% level. Hence, the null hypothesis, $H2b_0$, is rejected. The rest of the independent variables are not statistically significant at 10% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external R&D intensity*, on average, leads to an increase of 71.8 in the likelihood of occurrence of product innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.041 in the likelihood of occurrence of product innovation.

The PCRI3 model focuses on the relationship between process innovation and *external R&D intensity*, which is shown in Table 113. Because the Wald test and 5 of 6 individual z-statistics (not shown here) are not statistically significant, the PCRI3

model is not shown here. Hence, the null hypothesis, $H4b_0$, could not be tested for manufacture of fabricated metal products, except machinery and equipment.

Table 113: Regression Results of PDRI3 and PCRI3 Models – C-25

Variable Name	PDRI3			PCRI3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extrdint</i>	224.50	0.021 **	71.796			
<i>rdperint</i>	-0.4050	0.759	-0.1295			
<i>IntoverD</i>	0.0443	0.638	0.0142			
<i>HHI</i>	24.199	0.979	7.7388			
<i>phd_ma</i>	0.1272	0.027 **	0.0407			
<i>ipicsec</i>	-0.0021	0.778	-0.0007			

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI3: Wald $\chi^2(6) = 17.32$ Prob > $\chi^2 = 0.0082$

For PCRI3: Wald $\chi^2(6) = 10.62$ Prob > $\chi^2 = 0.1007$

Regression results of PDRI4 and PCRI4 models include coefficient, p-value, and average marginal effect, which are shown in Table 114. These models analyze the effect of *external-domestic R&D intensity* on the probability of product and process innovations, respectively.

The PDRI4 model focuses on the relationship between product innovation and *external-domestic R&D intensity*, which is shown in Table 114. In this model, *external-domestic R&D intensity* and the *number of highly educated R&D personnel* are statistically significant at 10% and 5% level, respectively. Hence, the null hypothesis, $H2c_0$, is rejected. The rest of the independent variables are not statistically significant at 10% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external-domestic R&D intensity*, on average, leads to an increase of 230.58 in the likelihood of occurrence of product innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.038 in the likelihood of occurrence of product innovation.

The PCRI4 model focuses on the relationship between process innovation and *external-domestic R&D intensity*, which is shown in Table 114. Because the Wald test

and 5 of 6 individual z-statistics (not shown here) are not statistically significant, the PCRI4 model is not shown here. Hence, the null hypothesis, $H4c_0$, could not be tested for manufacture of fabricated metal products, except machinery and equipment.

Table 114: Regression Results of PDRI4 and PCRI4 Models – C-25

Variable Name	PDRI4			PCRI4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extdomrdint</i>	728.32	0.071 *	230.58			
<i>rdperint</i>	-0.4189	0.751	-0.1326			
<i>IntoverD</i>	0.0468	0.616	0.0148			
<i>HHI</i>	46.178	0.958	14.619			
<i>phd_ma</i>	0.1189	0.035 **	0.0376			
<i>ipicsec</i>	-0.0019	0.793	-0.0006			

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI4: Wald $\chi^2(6)=14.21$ Prob > $\chi^2=0.0274$

For PCRI4: Wald $\chi^2(6)=9.60$ Prob > $\chi^2=0.1424$

Regression results of PDRI5 and PCRI5 models include coefficient, p-value, and average marginal effect, which are shown in Table 115. These models analyze the effect of *external-foreign R&D intensity* on the probability of product and process innovations, respectively.

The PDRI5 model focuses on the relationship between product innovation and *external-foreign R&D intensity*, which is shown in Table 115. Because the Wald test and 5 of 6 individual z-statistics (not shown here) are not statistically significant, the PDRI5 model is not shown here. Hence, the null hypothesis $H2d_0$, could not be tested for manufacture of fabricated metal products, except machinery and equipment.

Table 115: Regression Results of PDRI5 and PCRI5 Models – C-25

Variable Name	PDRI5			PCRI5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extfrgrdint</i>				-273.04	0.000 ***	-83.793
<i>rdperint</i>				0.7224	0.506	0.2217
<i>IntoverD</i>				0.1186	0.160	0.0364
<i>HHI</i>				-245.21	0.768	-75.254
<i>phd_ma</i>				0.1089	0.031 **	0.0334
<i>ipicsec</i>				-0.0022	0.744	-0.0007

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI5: Wald $\chi^2(6)=10.30$ Prob > $\chi^2=0.1125$

For PCRI5: Wald $\chi^2(6)=48.46$ Prob > $\chi^2=0.0000$

The PCRI5 model focuses on the relationship between process innovation and *external-foreign R&D intensity*, which is shown in Table 115. In this model, *external-foreign R&D intensity* and the *number of highly educated R&D personnel* are statistically significant at 1% and 5% level, respectively. Hence, the null hypothesis, $H4d_0$, is rejected. The rest of the independent variables are not statistically significant at 10% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external-foreign R&D intensity*, on average, leads to a decrease of 83.79 in the likelihood of occurrence of product innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.033 in the likelihood of occurrence of product innovation.

According to the analysis of the manufacture of fabricated metal products (except machinery and equipment), there are many findings in terms of product innovation. These are:

- R&D expenditure variables except external and external-foreign are statistically significant and have positive effect on the likelihood of occurrence of product innovation in Turkish manufacturing industry. The most effective one is *total R&D expenditure*.
- R&D intensity variables except external-foreign are statistically significant and have positive effect on the likelihood of occurrence of product innovation in Turkish manufacturing industry. The most effective one is *external-domestic R&D intensity*.
- The other independent variables are interpreted by focusing on the PDRE1 and PDRI1 models. Because these models cover *total R&D expenditures*. According to the PDRE1 model and the PDRI1 model, the *number of highly educated R&D personnel* are statistically significant and has positive effect on the likelihood of occurrence of product innovation. It means that more highly educated R&D personnel increases the likelihood

of occurrence of product innovation in the manufacture of fabricated metal products (except machinery and equipment).

According to the analysis of the manufacture of fabricated metal products (except machinery and equipment), there are many findings in terms of process innovation. These are:

- R&D expenditure variables are not statistically significant at 10% level and PCRE4 model is not statistically according to the Wald test.
- R&D intensity variables except external-foreign are not statistically significant at 10% level. *External-foreign R&D intensity* has negative effect on the likelihood of occurrence of process innovation. This result does not meet the hypothesis.
- The other independent variables are interpreted by focusing on the PCRE1 and PCRI1 models. Because these models cover *total R&D expenditures*. According to the PCRE1 model, the *number of highly educated R&D personnel* are statistically significant and has positive effect on the likelihood of occurrence of process innovation. It means that more highly educated R&D personnel increases the likelihood of occurrence of process innovation in manufacture of fabricated metal products (except machinery and equipment). the PCRI1 model is not statistically significant according to the Wald test.

Results of the analyses are also viewed by comparing product and process innovation in terms of manufacture of fabricated metal products (except machinery and equipment). These are:

- *Total, internal, and external-domestic R&D expenditure* affect only the likelihood of occurrence of product innovation positively.
- *Total, internal, external, and external-domestic R&D intensity* affect only the likelihood of occurrence of product innovation positively.
- *External-foreign R&D intensity* affects only the likelihood of occurrence of process innovation negatively.

4.2.2.9. Manufacture of Computer, Electronic and Optical Products, C-26 by NACE Rev. 2

Firms that are engaged in R&D in manufacture of computer, electronic and optical products are analyzed with twenty models such as 10 product innovation models and 10 process innovation models.

Regression results of PDRE1 and PCRE1 models include coefficient, p-value, and average marginal effect, which are shown in Table 116. These models analyze the effect of *total R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE1 model focuses on the relationship between product innovation and *total R&D expenditure*, which is shown in Table 116. In this model, independent variables except *total R&D expenditure* are not statistically significant at 10% level. *Total R&D expenditure* is statistically significant at the 10% level. Hence, the null hypothesis, $H1_0$, is rejected. It means that 1 percent increase in the value of *total R&D expenditure*, on average, leads to an increase of 3.48 percent in the likelihood of occurrence of product innovation.

Table 116: Regression Results of PDRE1 and PCRE1 Models – C-26

Variable Name	PDRE1			PCRE1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntrdexpD</i>	0.1706	0.076 *	0.0348	-0.2604	0.047 **	-0.0642
<i>rdperint</i>	-0.6036	0.145	-0.1230	0.6173	0.102	0.1522
<i>IntoverD</i>	-0.0315	0.816	-0.0064	0.3275	0.026 **	0.0807
<i>HHI</i>	5.3604	0.421	1.0927	-0.1957	0.977	-0.0483
<i>phd_ma</i>	0.0068	0.292	0.0014	0.0410	0.045 **	0.0101
<i>ipicsec</i>	0.0002	0.966	0.0000	0.0051	0.256	0.0013

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE1: Wald $\chi^2(6)=16.80$ Prob > $\chi^2=0.0101$

For PCRE1: Wald $\chi^2(6)=14.65$ Prob > $\chi^2=0.0232$

The PCRE1 model focuses on the relationship between process innovation and *total R&D expenditure*, which is shown in Table 116. In this model, independent variables such as *total R&D expenditure*, *turnover*, and the *number of highly educated R&D personnel* are statistically significant at 5% level. However, the effect of *total R&D expenditure* on process innovation is negative. Hence, the null hypothesis, $H3_0$,

is not rejected. It means that *total R&D expenditure* does not increase the likelihood of occurrence of process innovation, and it is harder to make a new process innovation with this type of expenditure in manufacture of computer, electronic and optical products. In other words, there is fishing-out case where ϕ is less than 0. The rest of the independent variables are not statistically significant at 10% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *total R&D expenditure*, on average, leads to a decrease of 6.42 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 8.07 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.011 in the likelihood of occurrence of process innovation.

Regression results of PDRE2 and PCRE2 models include coefficient, p-value, and average marginal effect, which are shown in Table 117. These models analyze the effect of *internal R&D expenditure* on the probability of product and process innovations, respectively.

Table 117: Regression Results of PDRE2 and PCRE2 Models – C-26

Variable Name	PDRE2			PCRE2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntintrdexpD</i>	0.1720	0.073 *	0.0351	-0.2784	0.028 **	-0.0685
<i>rdperint</i>	-0.6008	0.144	-0.1227	0.6355	0.094 *	0.1564
<i>IntoverD</i>	-0.0349	0.796	-0.0071	0.3413	0.020 **	0.0840
<i>HHI</i>	5.2153	0.433	1.0653	-0.0563	0.994	-0.0139
<i>phd_ma</i>	0.0068	0.264	0.0014	0.0428	0.039 **	0.0105
<i>ipicsec</i>	0.0000	0.994	0.0000	0.0054	0.224	0.0013

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE2: Wald chi2(6)=16.99 Prob > chi2=0.0093

For PCRE2: Wald chi2(6)=15.53 Prob > chi2=0.0165

The PDRE2 model focuses on the relationship between product innovation and *internal R&D expenditure*, which is shown in Table 117. In this model, independent variables except *internal R&D expenditure* are not statistically significant at 10%

level. *Internal R&D expenditure* is statistically significant at the 10% level. Hence, the null hypothesis, $H1a_0$, is rejected. It means that a 1 percent increase in the value of *total R&D expenditure*, on average, leads to an increase of 3.51 percent in the likelihood of occurrence of product innovation.

The PCRE2 model focuses on the relationship between process innovation and *internal R&D expenditure*, which is shown in Table 117. In this model, independent variables except *HHI* and *industrial production index by manufacturing industry* are not statistically significant at 10% level. *Internal R&D expenditure*, *turnover*, and the *number of highly educated R&D personnel* are statistically significant at 5% level, and *R&D personnel intensity* at 10% level. However, the effect of *internal R&D expenditure* on process innovation is negative. Hence, the null hypothesis, $H3a_0$, is not rejected. It means that *internal R&D expenditure* does not increase the likelihood of occurrence of process innovation, and it is harder to make a new process innovation with this type of expenditure in manufacture of computer, electronic and optical products. In other words, there is fishing-out case where ϕ is less than 0. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *internal R&D expenditure*, on average, leads to a decrease of 6.85 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.16 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 8.4 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.011 in the likelihood of occurrence of process innovation.

Regression results of PDRE3 and PCRE3 models include coefficient, p-value, and average marginal effect, which are shown in Table 118. These models analyze the

effect of *external R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE3 model focuses on the relationship between product innovation and *external R&D expenditure*, which is shown in Table 118. In this model, independent variables except the *number of highly educated R&D personnel* are not statistically significant at 10% level. Hence, the null hypothesis, $H1b_0$, is not rejected. The *number of highly educated R&D personnel* is statistically significant at the 5% level. It means that a unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.003 in the likelihood of occurrence of product innovation.

Table 118: Regression Results of PDRE3 and PCRE3 Models – C-26

Variable Name	PDRE3			PCRE3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpD</i>	-0.0045	0.835	-0.0009	-0.0299	0.287	-0.0073
<i>rdperint</i>	-0.2563	0.496	-0.0545	0.1330	0.683	0.0327
<i>IntoverD</i>	0.0572	0.625	0.0122	0.1878	0.082 *	0.0461
<i>HHI</i>	6.5745	0.345	1.3969	-3.0897	0.676	-0.7587
<i>phd_ma</i>	0.0156	0.048 **	0.0033	0.0251	0.057 *	0.0062
<i>ipicsec</i>	0.0004	0.920	0.0001	0.0032	0.539	0.0008

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE3: Wald $\chi^2(6)=16.19$ Prob > $\chi^2=0.0128$

For PCRE3: Wald $\chi^2(6)=15.48$ Prob > $\chi^2=0.0168$

The PCRE3 model focuses on the relationship between process innovation and *external R&D expenditure*, which is shown in Table 118. In this model, independent variables except *turnover* and the *number of highly educated R&D personnel* are not statistically significant at 10% level. Hence, the null hypothesis, $H3b_0$, is not rejected. *Turnover* and the *number of highly educated R&D personnel* are statistically significant at the 10% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.61 percent in the likelihood of occurrence of process innovation.

- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.006 in the likelihood of occurrence of process innovation.

Regression results of PDRE4 and PCRE4 models include coefficient, p-value, and average marginal effect, which are shown in Table 119. These models analyze the effect of *external-domestic R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE4 model focuses on the relationship between product innovation and *external-domestic R&D expenditure*, which is shown in Table 119. In this model, independent variables except the *number of highly educated R&D personnel* are not statistically significant at 10% level. Hence, the null hypothesis, $H1_{c0}$, is not rejected. The *number of highly educated R&D personnel* is statistically significant at the 5% level. It means that a unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.003 in the likelihood of occurrence of product innovation.

Table 119: Regression Results of PDRE4 and PCRE4 Models – C-26

Variable Name	PDRE4			PCRE4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpdomD</i>	-0.0063	0.780	-0.0013	-0.0330	0.263	-0.0081
<i>rdperint</i>	-0.2529	0.503	-0.0538	0.1438	0.660	0.0353
<i>IntoverD</i>	0.0565	0.629	0.0120	0.1869	0.083 *	0.0459
<i>HHI</i>	6.5077	0.352	1.3836	-3.1986	0.665	-0.7849
<i>phd_ma</i>	0.0156	0.045 **	0.0033	0.0252	0.053 *	0.0062
<i>ipicsec</i>	0.0004	0.931	0.0001	0.0031	0.551	0.0008

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE4: Wald $\chi^2(6) = 16.35$ Prob > $\chi^2 = 0.0120$

For PCRE4: Wald $\chi^2(6) = 15.65$ Prob > $\chi^2 = 0.0157$

The PCRE4 model focuses on the relationship between process innovation and *external-domestic R&D expenditure*, which is shown in Table 119. In this model, independent variables except *turnover* and the *number of highly educated R&D personnel* are not statistically significant at 10% level. Hence, the null hypothesis, $H3_{c0}$, is not rejected. *Turnover* and the *number of highly educated R&D personnel* are

statistically significant at the 10% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.59 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.006 in the likelihood of occurrence of process innovation.

Regression results of PDRE5 and PCRE5 models include coefficient, p-value, and average marginal effect, which are shown in Table 120. These models analyze the effect of *external-foreign R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE5 model focuses on the relationship between product innovation and *external-foreign R&D expenditure*, which is shown in Table 120. In this model, independent variables except *external-foreign R&D expenditure* and the *number of highly educated R&D personnel* are not statistically significant at 10% level. *External-foreign R&D expenditure* is statistically significant at the 1% level. Hence, the null hypothesis, $H1d_0$, is rejected. The *number of highly educated R&D personnel* is statistically significant at the 10% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *external-foreign R&D expenditure*, on average, leads to an increase of 1.1 percent in the likelihood of occurrence of product innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.003 in the likelihood of occurrence of product innovation.

The PCRE5 model focuses on the relationship between process innovation and *external-foreign R&D expenditure*, which is shown in Table 120. In this model, independent variables except *turnover* and the *number of highly educated R&D personnel* are not statistically significant at 10% level. Hence, the null hypothesis,

$H3d_0$, is not rejected. *Turnover* and the *number of highly educated R&D personnel* are statistically significant at the 10% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.49 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.006 in the likelihood of occurrence of process innovation.

Table 120: Regression Results of PDRE5 and PCRE5 Models – C-26

Variable Name	PDRE5			PCRE5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpforD</i>	0.0520	0.000 ***	0.0110	-0.0298	0.631	-0.0074
<i>rdperint</i>	-0.2734	0.459	-0.0579	0.0749	0.816	0.0185
<i>IntoverD</i>	0.0547	0.646	0.0116	0.1820	0.096 *	0.0449
<i>HHI</i>	6.6478	0.315	1.4080	-1.9707	0.780	-0.4863
<i>phd_ma</i>	0.0154	0.051 *	0.0033	0.0259	0.085 *	0.0064
<i>ipicsec</i>	0.0005	0.894	0.0001	0.0041	0.402	0.0010

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE5: Wald $\chi^2(6)=104.92$ Prob > $\chi^2=0.0000$

For PCRE5: Wald $\chi^2(6)=14.35$ Prob > $\chi^2=0.0260$

Regression results of PDRI1 and PCRI1 models include coefficient, p-value, and average marginal effect, which are shown in Table 121. These models analyze the effect of *total R&D intensity* on the probability of product and process innovations, respectively.

The PDRI1 model focuses on the relationship between product innovation and *total R&D intensity*, which is shown in Table 121. In this model, independent variables except the *number of highly educated R&D personnel* are not statistically significant at 10% level. Hence, the null hypothesis, $H2_0$, is not rejected. The *number of highly educated R&D personnel* is statistically significant at the 10% level. It means that a unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.003 in the likelihood of occurrence of product innovation.

The PCRI1 model focuses on the relationship between process innovation and *total R&D intensity*, which is shown in Table 121. In this model, independent variables except *turnover* and the *number of highly educated R&D personnel* are not statistically significant at 10% level. Hence, the null hypothesis, $H4_0$, is not rejected. *Turnover* and the *number of highly educated R&D personnel* are statistically significant at the 10% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.51 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.006 in the likelihood of occurrence of process innovation.

Table 121: Regression Results of PDRI1 and PCRI1 Models – C-26

Variable Name	PDRI1			PCRI1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>totrdint</i>	0.6134	0.439	0.1288	0.2296	0.749	0.0568
<i>rdperint</i>	-0.3758	0.405	-0.0789	0.0029	0.993	0.0007
<i>lntoverD</i>	0.0710	0.549	0.0149	0.1823	0.092 *	0.0451
<i>HHI</i>	6.6578	0.321	1.3979	-2.2443	0.752	-0.5550
<i>phd_ma</i>	0.0134	0.099 *	0.0028	0.0247	0.096 *	0.0061
<i>ipicsec</i>	0.0006	0.875	0.0001	0.0040	0.418	0.0010

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI1: Wald $\chi^2(6)=14.20$ Prob > $\chi^2=0.0275$

For PCRI1: Wald $\chi^2(6)=14.52$ Prob > $\chi^2=0.0244$

Regression results of PDRI2 and PCRI2 models include coefficient, p-value, and average marginal effect, which are shown in Table 122. These models analyze the effect of *internal R&D intensity* on the probability of product and process innovations, respectively.

The PDRI2 model focuses on the relationship between product innovation and *internal R&D intensity*, which is shown in Table 122. In this model, independent variables are not statistically significant at 10% level. Hence, the null hypothesis, $H2a_0$, is not rejected.

The PCRI2 model focuses on the relationship between process innovation and *internal R&D intensity*, which is shown in Table 122. In this model, independent

variables except the *number of highly educated R&D personnel* are not statistically significant at 10% level. Hence, the null hypothesis, $H4a_0$, is not rejected. The *number of highly educated R&D personnel* is statistically significant at the 10% level. It means that a unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.008 in the likelihood of occurrence of process innovation.

Table 122: Regression Results of PDRI2 and PCRI2 Models – C-26

Variable Name	PDRI2			PCRI2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>intrdint</i>	1.1211	0.463	0.2357	-1.5681	0.360	-0.3885
<i>rdperint</i>	-0.4582	0.394	-0.0963	0.3929	0.448	0.0973
<i>IntoverD</i>	0.0734	0.528	0.0154	0.1643	0.128	0.0407
<i>HHI</i>	6.5539	0.327	1.3780	-1.8059	0.799	-0.4474
<i>phd_ma</i>	0.0121	0.123	0.0026	0.0315	0.060 *	0.0078
<i>ipicsec</i>	0.0005	0.898	0.0001	0.0041	0.394	0.0010

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI2: Wald $\chi^2(6) = 12.50$ Prob > $\chi^2 = 0.0517$

For PCRI2: Wald $\chi^2(6) = 14.54$ Prob > $\chi^2 = 0.0241$

Regression results of PDRI3 and PCRI3 models include coefficient, p-value, and average marginal effect, which are shown in Table 123. These models analyze the effect of *external R&D intensity* on the probability of product and process innovations, respectively.

The PDRI3 model focuses on the relationship between product innovation and *external R&D intensity*, which is shown in Table 123. In this model, independent variables except the *number of highly educated R&D personnel* are not statistically significant at 10% level. Hence, the null hypothesis, $H2b_0$, is not rejected. The *number of highly educated R&D personnel* is statistically significant at the 5% level. It means that a unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.003 in the likelihood of occurrence of product innovation.

The PCRI3 model focuses on the relationship between process innovation and *external R&D intensity*, which is shown in Table 123. In this model, independent variables except *external R&D intensity*, *turnover*, and the *number of highly educated R&D personnel* are not statistically significant at 10% level. *External R&D intensity*

is statistically significant at the 1% level. Hence, the null hypothesis, $H4b_0$, is rejected. *Turnover* and the *number of highly educated R&D personnel* are statistically significant at the 10% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external R&D intensity*, on average, leads to an increase of 0.24 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.57 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.006 in the likelihood of occurrence of process innovation.

Table 123: Regression Results of PDRI3 and PCRI3 Models – C-26

Variable Name	PDRI3			PCRI3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extrdint</i>	0.0241	0.930	0.0051	0.9623	0.001 ***	0.2369
<i>rdperint</i>	-0.2639	0.474	-0.0560	0.0342	0.916	0.0084
<i>lntoverD</i>	0.0586	0.621	0.0124	0.1857	0.087 *	0.0457
<i>HHI</i>	6.7367	0.311	1.4289	-2.2277	0.753	-0.5485
<i>phd_ma</i>	0.0154	0.049 **	0.0033	0.0255	0.084 *	0.0063
<i>ipicsec</i>	0.0005	0.885	0.0001	0.0041	0.403	0.0010

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI3: Wald $\chi^2(6)=27.26$ Prob > $\chi^2=0.0001$

For PCRI3: Wald $\chi^2(6)=22.29$ Prob > $\chi^2=0.0011$

Regression results of PDRI4 and PCRI4 models include coefficient, p-value, and average marginal effect, which are shown in Table 124. These models analyze the effect of *external-domestic R&D intensity* on the probability of product and process innovations, respectively.

The PDRI4 model focuses on the relationship between product innovation and *external-domestic R&D intensity*, which is shown in Table 124. In this model, independent variables except the *number of highly educated R&D personnel* are not statistically significant at 10% level. Hence, the null hypothesis, $H2c_0$, is not rejected. The *number of highly educated R&D personnel* is statistically significant at the 5% level. It means that a unit increase in the value of the *number of highly educated R&D*

personnel, on average, leads to an increase of 0.003 in the likelihood of occurrence of product innovation.

The PCRI4 model focuses on the relationship between process innovation and *external-domestic R&D intensity*, which is shown in Table 124. In this model, independent variables except *external-domestic R&D intensity*, *turnover*, and the *number of highly educated R&D personnel* are not statistically significant at 10% level. *External-domestic R&D intensity* is statistically significant at the 1% level. Hence, the null hypothesis, $H4c_0$, is rejected. *Turnover* and the *number of highly educated R&D personnel* are statistically significant at the 10% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external R&D intensity*, on average, leads to an increase of 0.24 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.57 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.006 in the likelihood of occurrence of process innovation.

Table 124: Regression Results of PDRI4 and PCRI4 Models – C-26

Variable Name	PDRI4			PCRI4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extdomrdint</i>	0.0225	0.934	0.0048	0.9598	0.001 ***	0.2363
<i>rdperint</i>	-0.2639	0.474	-0.0560	0.0342	0.915	0.0084
<i>IntoverD</i>	0.0586	0.621	0.0124	0.1856	0.087 *	0.0457
<i>HHI</i>	6.7368	0.311	1.4289	-2.2270	0.753	-0.5484
<i>phd_ma</i>	0.0154	0.049 **	0.0033	0.0255	0.084 *	0.0063
<i>ipicsec</i>	0.0005	0.885	0.0001	0.0041	0.403	0.0010

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI4: Wald $\chi^2(6)=27.07$ Prob > $\chi^2=0.0001$

For PCRI4: Wald $\chi^2(6)=22.06$ Prob > $\chi^2=0.0012$

Regression results of PDRI5 and PCRI5 models include coefficient, p-value, and average marginal effect, which are shown in Table 125. These models analyze the effect of *external-foreign R&D intensity* on the probability of product and process innovations, respectively.

The PDRI5 model focuses on the relationship between product innovation and *external-foreign R&D intensity*, which is shown in Table 125. In this model, independent variables except *external-foreign R&D intensity* and the *number of highly educated R&D personnel* are not statistically significant at 10% level. *External-foreign R&D intensity* is statistically significant at the 1% level. Hence, the null hypothesis, $H2d_0$, is rejected. The *number of highly educated R&D personnel* is statistically significant at the 5% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external-foreign R&D intensity*, on average, leads to an increase of 49.07 in the likelihood of occurrence of product innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.003 in the likelihood of occurrence of product innovation.

Table 125: Regression Results of PDRI5 and PCRI5 Models – C-26

Variable Name	PDRI5			PCRI5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extfrgrdint</i>	231.92	0.000 ***	49.070	121.49	0.487	30.111
<i>rdperint</i>	-0.2644	0.473	-0.056	0.0545	0.868	0.0135
<i>IntoverD</i>	0.0574	0.628	0.012	0.1779	0.094 *	0.0441
<i>HHI</i>	6.6852	0.313	1.414	-2.2527	0.749	-0.5583
<i>phd_ma</i>	0.0156	0.049 **	0.003	0.0254	0.080 *	0.0063
<i>ipicsec</i>	0.0005	0.888	0.000	0.0039	0.421	0.0010

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI5: Wald $\chi^2(6) = 40.51$ Prob > $\chi^2 = 0.0000$

For PCRI5: Wald $\chi^2(6) = 15.13$ Prob > $\chi^2 = 0.0192$

The PCRI5 model focuses on the relationship between process innovation and *external-foreign R&D intensity*, which is shown in Table 125. In this model, independent variables except *turnover* and the *number of highly educated R&D personnel* are not statistically significant at 10% level. Hence, the null hypothesis, $H4d_0$, is not rejected. *Turnover* and the *number of highly educated R&D personnel* are statistically significant at the 10% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.41 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.006 in the likelihood of occurrence of process innovation.

According to the analysis of the manufacture of computer, electronic and optical products, there are many findings in terms of product innovation. These are:

- R&D expenditure variables except external and external-domestic are statistically significant and have positive effect on the likelihood of occurrence of product innovation in Turkish manufacturing industry. The most effective one is *internal R&D expenditure*.
- R&D intensity variables except external-foreign are not statistically significant at 10% level. *External-foreign R&D intensity* has positive effect on the likelihood of occurrence of product innovation in Turkish manufacturing industry.
- The other independent variables are interpreted by focusing on the PDRE1 and PDRI1 models. Because these models cover *total R&D expenditures*. According to the PDRE1 model, these other independent variables are not statistically significant at 10% level. According to the PDRI1 model, only the *number of highly educated R&D personnel* are statistically significant and has positive effect on the likelihood of occurrence of product innovation. It means that more highly educated R&D personnel increases the likelihood of occurrence of product innovation in the manufacture of computer, electronic and optical products.

According to the analysis of the manufacture of computer, electronic and optical products, there are many findings in terms of process innovation. These are:

- R&D expenditure variables except total and internal are not statistically significant at 10% level. Total and *internal R&D expenditures* have negative effect on the likelihood of occurrence of process innovation in

Turkish manufacturing industry. The most effective one is *internal R&D expenditure*. These results do not meet the hypotheses.

- R&D intensity variables except external and external-domestic are not statistically significant at 10% level. External and external-domestic R&D intensities have positive effect on the likelihood of occurrence of process innovation.
- The other independent variables are interpreted by focusing on the PCRE1 and PCRI1 models. Because these models cover *total R&D expenditures*. According to PCRE1 and PCRI1 models, these other independent variables such as *turnover* and the *number of highly educated R&D personnel* are statistically significant and have positive effects on the likelihood of occurrence of process innovation. It means that more *turnover* and more highly educated R&D personnel increase the likelihood of occurrence of process innovation in the manufacture of computer, electronic and optical products.

Results of the analyses are also viewed by comparing product and process innovation in terms of manufacture of computer, electronic and optical products. These are:

- *Total* and *internal R&D expenditure* affect the likelihood of occurrence of product innovation positively, but the likelihood of occurrence of process innovation negatively.
- *External-foreign R&D expenditure* affects only the likelihood of occurrence of product innovation positively.
- *External* and *external-domestic R&D intensity* affect only the likelihood of occurrence of process innovation positively.
- *External-foreign R&D intensity* affects only the likelihood of occurrence of product innovation positively.

4.2.2.10. Manufacture of Electrical Equipment, C-27 by NACE Rev.

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Firms that are engaged in R&D in manufacture of electrical equipment are analyzed with twenty models such as 10 product innovation models and 10 process innovation models.

Regression results of PDRE1 and PCRE1 models include coefficient, p-value, and average marginal effect, which are shown in Table 126. These models analyze the effect of *total R&D expenditure* on the probability of product and process innovations, respectively.

Table 126: Regression Results of PDRE1 and PCRE1 Models – C-27

Variable Name	PDRE1			PCRE1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntrdexpD</i>	0.1292	0.205	0.0307	0.1122	0.275	0.0276
<i>rdperint</i>	-2.4001	0.089 *	-0.5692	0.1000	0.942	0.0246
<i>IntoverD</i>	-0.0767	0.426	-0.0182	0.1160	0.351	0.0285
<i>HHI</i>	-40.638	0.251	-9.6379	-4.2914	0.871	-1.0544
<i>phd_ma</i>	0.0536	0.078 *	0.0127	-0.0054	0.197	-0.0013
<i>ipicsec</i>	-0.0035	0.556	-0.0008	0.0058	0.284	0.0014

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE1: Wald chi2(6)=14.10 Prob > chi2=0.0285

For PCRE1: Wald chi2(6)=16.62 Prob > chi2=0.0108

The PDRE1 model focuses on the relationship between product innovation and *total R&D expenditure*, which is shown in Table 126. In this model, independent variables except *R&D personnel intensity* and the *number of highly educated R&D personnel* are not statistically significant at 10% level. Hence, the null hypothesis, $H1_0$, is not rejected. *R&D personnel intensity* and the *number of highly educated R&D personnel* are statistically significant at 10% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of R&D intensity, on average, leads to a decrease of 0.57 in the likelihood of occurrence of product innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.013 in the likelihood of occurrence of product innovation.

The PCRE1 model focuses on the relationship between process innovation and *total R&D expenditure*, which is shown in Table 126. In this model, independent variables are not statistically significant at 10% level. Hence, the null hypothesis, $H3_0$, is not rejected.

Regression results of PDRE2 and PCRE2 models include coefficient, p-value, and average marginal effect, which are shown in Table 127. These models analyze the effect of *internal R&D expenditure* on the probability of product and process innovations, respectively.

Table 127: Regression Results of PDRE2 and PCRE2 Models – C-27

Variable Name	PDRE2			PCRE2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntintrdexpD</i>	0.1670	0.071 *	0.0393	0.1078	0.299	0.0265
<i>rdperint</i>	-2.5120	0.066 *	-0.5915	0.1365	0.921	0.0336
<i>IntoverD</i>	-0.0946	0.315	-0.0223	0.1203	0.335	0.0296
<i>HHI</i>	-41.611	0.237	-9.7975	-4.0330	0.879	-0.9925
<i>phd_ma</i>	0.0463	0.091 *	0.0109	-0.0054	0.196	-0.0013
<i>ipicsec</i>	-0.0036	0.540	-0.0008	0.0058	0.279	0.0014

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE2: Wald $\chi^2(6) = 15.06$ Prob > $\chi^2 = 0.0198$

For PCRE2: Wald $\chi^2(6) = 16.12$ Prob > $\chi^2 = 0.0131$

The PDRE2 model focuses on the relationship between product innovation and *internal R&D expenditure*, which is shown in Table 127. In this model, independent variables such as *internal R&D expenditure*, *R&D personnel intensity*, and the *number of highly educated R&D personnel* are statistically significant at 10% level. Hence, the null hypothesis, $H1a_0$, is rejected. The rest of independent variables are not statistically significant at 10% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *internal R&D expenditure*, on average, leads to an increase of 3.93 percent in the likelihood of occurrence of product innovation.
- A unit increase in the value of R&D intensity, on average, leads to a decrease of 0.59 in the likelihood of occurrence of product innovation.

- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.011 in the likelihood of occurrence of product innovation.

The PCRE2 model focuses on the relationship between process innovation and *internal R&D expenditure*, which is shown in Table 127. In this model, independent variables are not statistically significant at 10% level. Hence, the null hypothesis, $H3a_0$, is not rejected.

Regression results of PDRE3 and PCRE3 models include coefficient, p-value, and average marginal effect, which are shown in Table 128. These models analyze the effect of *external R&D expenditure* on the probability of product and process innovations, respectively.

Table 128: Regression Results of PDRE3 and PCRE3 Models – C-27

Variable Name	PDRE3			PCRE3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpD</i>	-0.0017	0.927	-0.0004	0.0112	0.418	0.0028
<i>rdperint</i>	-1.9037	0.186	-0.4643	0.7780	0.533	0.1972
<i>IntoverD</i>	-0.0046	0.954	-0.0011	0.1850	0.028 **	0.0469
<i>HHI</i>	-38.806	0.249	-9.4644	-0.8645	0.973	-0.2191
<i>phd_ma</i>	0.0695	0.020 **	0.0169	-0.0041	0.381	-0.0010
<i>ipicsec</i>	-0.0029	0.606	-0.0007	0.0064	0.204	0.0016

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE3: Wald $\chi^2(6) = 12.31$ Prob > $\chi^2 = 0.0553$

For PCRE3: Wald $\chi^2(6) = 10.22$ Prob > $\chi^2 = 0.0000$

The PDRE3 model focuses on the relationship between product innovation and *external R&D expenditure*, which is shown in Table 128. In this model, independent variables except the *number of highly educated R&D personnel* are not statistically significant at 10% level. Hence, the null hypothesis, $H1b_0$, is not rejected. The *number of highly educated R&D personnel* is statistically significant at 5% level. It means that a unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.017 in the likelihood of occurrence of product innovation.

The PCRE3 model focuses on the relationship between process innovation and *external R&D expenditure*, which is shown in Table 128. In this model, independent

variables except *turnover* are not statistically significant at the 10% level. Hence, the null hypothesis, $H3b_0$, is not rejected. *Turnover* is statistically significant at the 5% level. It means that a 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.69 percent in the likelihood of occurrence of process innovation.

Regression results of PDRE4 and PCRE4 models include coefficient, p-value, and average marginal effect, which are shown in Table 129. These models analyze the effect of *external-domestic R&D expenditure* on the probability of product and process innovations, respectively.

Table 129: Regression Results of PDRE4 and PCRE4 Models – C-27

Variable Name	PDRE4			PCRE4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpdomD</i>	0.0132	0.471	0.0032	0.0123	0.323	0.0031
<i>rdperint</i>	-1.9179	0.185	-0.4673	0.7712	0.538	0.1955
<i>IntoverD</i>	-0.0051	0.949	-0.0012	0.1864	0.026 **	0.0473
<i>HHI</i>	-38.634	0.250	-9.4139	-0.8492	0.974	-0.2153
<i>phd_ma</i>	0.0673	0.023 **	0.0164	-0.0042	0.371	-0.0011
<i>ipicsec</i>	-0.0030	0.593	-0.0007	0.0062	0.215	0.0016

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE4: Wald $\chi^2(6)=13.83$ Prob > $\chi^2=0.0316$

For PCRE4: Wald $\chi^2(6)=10.74$ Prob > $\chi^2=0.0968$

The PDRE4 model focuses on the relationship between product innovation and *external-domestic R&D expenditure*, which is shown in Table 129. In this model, independent variables except the *number of highly educated R&D personnel* are not statistically significant at 10% level. Hence, the null hypothesis, $H1c_0$, is not rejected. The *number of highly educated R&D personnel* is statistically significant at 5% level. It means that a unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.016 in the likelihood of occurrence of product innovation.

The PCRE4 model focuses on the relationship between process innovation and *external-domestic R&D expenditure*, which is shown in Table 129. In this model, independent variables except *turnover* are not statistically significant at the 10% level. Hence, the null hypothesis, $H3c_0$, is not rejected. *Turnover* is statistically significant at the 5% level. It means that a 1 percent increase in the value of *turnover*, on average,

leads to an increase of 4.73 percent in the likelihood of occurrence of process innovation.

Regression results of PDRE5 and PCRE5 models include coefficient, p-value, and average marginal effect, which are shown in Table 130. These models analyze the effect of *external-foreign R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE5 model focuses on the relationship between product innovation and *external-foreign R&D expenditure*, which is shown in Table 130. In this model, independent variables except the *number of highly educated R&D personnel* are not statistically significant at 10% level. Hence, the null hypothesis, $H1d_0$, is not rejected. The *number of highly educated R&D personnel* is statistically significant at 5% level. It means that a unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.017 in the likelihood of occurrence of product innovation.

Table 130: Regression Results of PDRE5 and PCRE5 Models – C-27

Variable Name	PDRE5			PCRE5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpforD</i>	-0.0105	0.687	-0.0026			
<i>rdperint</i>	-1.9002	0.187	-0.4636			
<i>IntoverD</i>	-0.0016	0.983	-0.0004			
<i>HHI</i>	-39.572	0.231	-9.6542			
<i>phd_ma</i>	0.0698	0.019 **	0.0170			
<i>ipicsec</i>	-0.0031	0.578	-0.0008			

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE5: Wald $\chi^2(6)=12.30$ Prob > $\chi^2=0.0555$

For PCRE5: Wald $\chi^2(6)=10.32$ Prob > $\chi^2=0.1120$

The PCRE5 model focuses on the relationship between process innovation and *external-foreign R&D expenditure*, which is shown in Table 130. Because the Wald test and 5 of 6 individual z-statistics (not shown here) are not statistically significant, the PCRE5 model is not shown here. Hence, the null hypothesis, $H3d_0$, could not be tested for manufacture of electrical equipment.

Regression results of PDRI1 and PCRI1 models include coefficient, p-value, and average marginal effect, which are shown in Table 131. These models analyze the

effect of *total R&D intensity* on the probability of product and process innovations, respectively.

The PDRI1 model focuses on the relationship between product innovation and *total R&D intensity*, which is shown in Table 131. In this model, independent variables except the *number of highly educated R&D personnel* are not statistically significant at 10% level. Hence, the null hypothesis, H_{20} , is not rejected. The *number of highly educated R&D personnel* is statistically significant at 5% level. It means that a unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.016 in the likelihood of occurrence of product innovation.

The PCRI1 model focuses on the relationship between process innovation and *total R&D intensity*, which is shown in Table 131. Because the Wald test and 5 of 6 individual z-statistics (not shown here) are not statistically significant, the PCRI1 model is not shown here. Hence, the null hypothesis, H_{40} , could not be tested for manufacture of electrical equipment.

Table 131: Regression Results of PDRI1 and PCRI1 Models – C-27

Variable Name	PDRI1			PCRI1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>totrdint</i>	4.5864	0.428	1.1113			
<i>rdperint</i>	-2.4617	0.114	-0.5965			
<i>IntoverD</i>	0.0144	0.864	0.0035			
<i>HHI</i>	-42.367	0.218	-10.265			
<i>phd_ma</i>	0.0646	0.019 **	0.0156			
<i>ipicsec</i>	-0.0036	0.524	-0.0009			

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI1: Wald $\chi^2(6)=12.64$ Prob > $\chi^2=0.0490$

For PCRI1: Wald $\chi^2(6)=8.83$ Prob > $\chi^2=0.1832$

Regression results of PDRI2 and PCRI2 models include coefficient, p-value, and average marginal effect, which are shown in Table 132. These models analyze the effect of *internal R&D intensity* on the probability of product and process innovations, respectively.

The PDRI2 model focuses on the relationship between product innovation and *internal R&D intensity*, which is shown in Table 132. In this model, independent variables except the *number of highly educated R&D personnel* are not statistically

significant at 10% level. Hence, the null hypothesis, $H2a_0$, is not rejected. The *number of highly educated R&D personnel* is statistically significant at 5% level. It means that a unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.015 in the likelihood of occurrence of product innovation.

The PCRI2 model focuses on the relationship between process innovation and *internal R&D intensity*, which is shown in Table 132. Because the Wald test and 5 of 6 individual z-statistics (not shown here) are not statistically significant, the PCRI2 model is not shown here. Hence, the null hypothesis, $H4a_0$, could not be tested for manufacture of electrical equipment.

Table 132: Regression Results of PDRI2 and PCRI2 Models – C-27

Variable Name	PDRI2			PCRI2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>intrdint</i>	5.2453	0.393	1.2708			
<i>rdperint</i>	-2.5428	0.105	-0.6160			
<i>lntoverD</i>	0.0174	0.836	0.0042			
<i>HHI</i>	-42.831	0.209	-10.377			
<i>phd_ma</i>	0.0634	0.019 **	0.0154			
<i>ipicsec</i>	-0.0037	0.514	-0.0009			

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI2: Wald $\chi^2(6)=12.63$ Prob > $\chi^2=0.0492$

For PCRI2: Wald $\chi^2(6)=8.88$ Prob > $\chi^2=0.1805$

Regression results of PDRI3 and PCRI3 models include coefficient, p-value, and average marginal effect, which are shown in Table 133. These models analyze the effect of *external R&D intensity* on the probability of product and process innovations, respectively.

The PDRI3 model focuses on the relationship between product innovation and *external R&D intensity*, which is shown in Table 133. In this model, independent variables except the *number of highly educated R&D personnel* are not statistically significant at 10% level. Hence, the null hypothesis, $H2b_0$, is not rejected. The *number of highly educated R&D personnel* is statistically significant at 5% level. It means that a unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.016 in the likelihood of occurrence of product innovation.

Table 133: Regression Results of PDRI3 and PCRI3 Models – C-27

Variable Name	PDRI3			PCRI3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extrdint</i>	-21.298	0.431	-5.2042			
<i>rdperint</i>	-1.9040	0.184	-0.4652			
<i>IntoverD</i>	-0.0018	0.982	-0.0004			
<i>HHI</i>	-37.913	0.263	-9.2641			
<i>phd_ma</i>	0.0672	0.016 **	0.0164			
<i>ipicsec</i>	-0.0027	0.635	-0.0006			

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI3: Wald chi2(6)=12.59 Prob > chi2=0.0501

For PCRI3: Wald chi2(6)=8.63 Prob > chi2=0.1956

The PCRI3 model focuses on the relationship between process innovation and *external R&D intensity*, which is shown in Table 133. Because the Wald test and 5 of 6 individual z-statistics (not shown here) are not statistically significant, the PCRI3 model is not shown here. Hence, the null hypothesis, $H4b_0$, could not be tested for manufacture of electrical equipment.

Regression results of PDRI4 and PCRI4 models include coefficient, p-value, and average marginal effect, which are shown in Table 134. These models analyze the effect of *external-domestic R&D intensity* on the probability of product and process innovations, respectively.

Table 134: Regression Results of PDRI4 and PCRI4 Models – C-27

Variable Name	PDRI4			PCRI4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extdomrdint</i>	0.5789	0.979	0.1412	26.822	0.157	6.8054
<i>rdperint</i>	-1.9065	0.186	-0.4649	0.8269	0.510	0.2098
<i>IntoverD</i>	-0.0050	0.950	-0.0012	0.1903	0.023 **	0.0483
<i>HHI</i>	-38.780	0.251	-9.4560	-1.3386	0.959	-0.3396
<i>phd_ma</i>	0.0694	0.015 **	0.0169	-0.0041	0.376	-0.0010
<i>ipicsec</i>	-0.0029	0.610	-0.0007	0.0061	0.232	0.0016

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI4: Wald chi2(6)=12.30 Prob > chi2=0.0557

For PCRI4: Wald chi2(6)=16.27 Prob > chi2=0.0124

The PDRI4 model focuses on the relationship between product innovation and *external-domestic R&D intensity*, which is shown in Table 134. In this model, independent variables except the *number of highly educated R&D personnel* are not statistically significant at 10% level. Hence, the null hypothesis, $H2c_0$, is not rejected.

The *number of highly educated R&D personnel* is statistically significant at 5% level. It means that a unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.017 in the likelihood of occurrence of product innovation.

The PCRI4 model focuses on the relationship between process innovation and *external-domestic R&D expenditure*, which is shown in Table 134. In this model, independent variables except *turnover* are not statistically significant at the 10% level. Hence, the null hypothesis, $H4c_0$, is not rejected. *Turnover* is statistically significant at the 5% level. It means that a 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.83 percent in the likelihood of occurrence of product innovation.

Regression results of PDRI5 and PCRI5 models include coefficient, p-value, and average marginal effect, which are shown in Table 135. These models analyze the effect of *external-foreign R&D intensity* on the probability of product and process innovations, respectively.

Table 135: Regression Results of PDRI5 and PCRI5 Models – C-27

Variable Name	PDRI5			PCRI5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extfrgrdint</i>	-47.681	0.287	-11.645			
<i>rdperint</i>	-1.8804	0.191	-0.4592			
<i>IntoverD</i>	0.0012	0.988	0.0003			
<i>HHI</i>	-40.482	0.211	-9.8865			
<i>phd_ma</i>	0.0673	0.016 **	0.0164			
<i>ipicsec</i>	-0.0033	0.556	-0.0008			

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI5: Wald $\chi^2(6) = 13.23$ Prob > $\chi^2 = 0.0395$

For PCRI5: Wald $\chi^2(6) = 8.79$ Prob > $\chi^2 = 0.1858$

The PDRI5 model focuses on the relationship between product innovation and *external-foreign R&D intensity*, which is shown in Table 135. In this model, independent variables except the *number of highly educated R&D personnel* are not statistically significant at 10% level. Hence, the null hypothesis, $H2d_0$, is not rejected. The *number of highly educated R&D personnel* is statistically significant at 5% level. It means that a unit increase in the value of the *number of highly educated R&D*

personnel, on average, leads to an increase of 0.016 in the likelihood of occurrence of product innovation.

The PCRI5 model focuses on the relationship between process innovation and *external-foreign R&D expenditure*, which is shown in Table 135. Because the Wald test and 5 of 6 individual z-statistics (not shown here) are not statistically significant, the PCRI5 model is not shown here. Hence, the null hypothesis, $H4d_0$, could not be tested for manufacture of electrical equipment.

According to the analysis of the manufacture of electrical equipment, there are many findings in terms of product innovation. These are:

- Only *internal R&D expenditure* is statistically significant and has positive effect on the likelihood of occurrence of product innovation in Turkish manufacturing industry.
- R&D intensity variables are not statistically significant at 10% level.
- The other independent variables are interpreted by focusing on the PDRE1 and PDRI1 models. Because these models cover *total R&D expenditures*. According to the PDRE1 model, *R&D personnel intensity* and the *number of highly educated R&D personnel* are statistically significant and have negative and positive effects respectively on the likelihood of occurrence of product innovation. According to the PDRI1 model, only the *number of highly educated R&D personnel* are statistically significant and has positive effect on the likelihood of occurrence of product innovation. It means that more *R&D personnel intensity* decreases the likelihood of occurrence of product innovation. In addition, more highly educated R&D personnel increases in the manufacture of electrical equipment.

According to the analysis of the manufacture of electrical equipment, there are many findings in terms of process innovation. These are:

- In the manufacture of electrical equipment, all R&D expenditure variables and all R&D intensity variables are not statistically significant in terms of the likelihood of occurrence of product innovation. PCRE5, PCRI1,

PCRI2, PCRI3, and PCRI4 models are not statistically according to the Wald test.

- The other independent variables are interpreted by focusing on the PCRE1 and PCRI1 models. Because these models cover *total R&D expenditures*. According to the PCRE1 model, other independent variables are not statistically significant at 10% level. PCRI1 model is not statistically significant according to the Wald test.

Results of the analyses are also viewed by comparing product and process innovation in terms of manufacture of electrical equipment. These are:

- *Internal R&D expenditure* affects only the likelihood of occurrence of product innovation positively.

4.2.2.11. Manufacture of Machinery and Equipment n.e.c., C-28 by NACE Rev. 2

Firms that are engaged in R&D in manufacture of machinery and equipment n.e.c. are analyzed with twenty models such as 10 product innovation models and 10 process innovation models.

Regression results of PDRE1 and PCRE1 models include coefficient, p-value, and average marginal effect, which are shown in Table 136. These models analyze the effect of *total R&D expenditure* on the probability of product and process innovations, respectively.

Table 136: Regression Results of PDRE1 and PCRE1 Models – C-28

Variable Name	PDRE1			PCRE1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntrdexpD</i>				0.0091	0.919	0.0027
<i>rdperint</i>				0.4091	0.666	0.1200
<i>IntoverD</i>				0.1703	0.151	0.0499
<i>HHI</i>				766.23	0.002 ***	224.71
<i>phd_ma</i>				-0.0077	0.757	-0.0022
<i>ipicsec</i>				-0.0061	0.142	-0.0018

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE1: Wald chi2(6)=5.25 Prob > chi2=0.5118

For PCRE1: Wald chi2(6)=24.96 Prob > chi2=0.0003

The PDRE1 model focuses on the relationship between product innovation and *total R&D expenditure*, which is shown in Table 136. Because the Wald test and all individual z-statistics (not shown here) are not statistically significant, the PDRE1 model is not shown here. Hence, the null hypothesis, $H1_0$, could not be tested for manufacture of machinery and equipment n.e.c..

The PCRE1 model focuses on the relationship between process innovation and *total R&D expenditure*, which is shown in Table 136. In this model, independent variables except *HHI* are not statistically significant at 10% level. Hence, the null hypothesis, $H3_0$, is not rejected. *HHI* is statistically significant at the 1% level. It means, *ceteris paribus*, that an increase in *HHI* of 0.01, on average, leads to an increase of 224.71 in the likelihood of occurrence of process innovation.

Regression results of PDRE2 and PCRE2 models include coefficient, p-value, and average marginal effect, which are shown in Table 137. These models analyze the effect of *internal R&D expenditure* on the probability of product and process innovations, respectively.

Table 137: Regression Results of PDRE2 and PCRE2 Models – C-28

Variable Name	PDRE2			PCRE2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntintrdexpD</i>				0.0269	0.768	0.0079
<i>rdperint</i>				0.3470	0.706	0.1016
<i>IntoverD</i>				0.1569	0.188	0.0459
<i>HHI</i>				767.99	0.002 ***	224.90
<i>phd_ma</i>				-0.0082	0.742	-0.0024
<i>ipicsec</i>				-0.0061	0.142	-0.0018

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE2: Wald chi2(6)=5.20 Prob > chi2=0.5182

For PCRE2: Wald chi2(6)=25.19 Prob > chi2=0.0003

The PDRE2 model focuses on the relationship between product innovation and *internal R&D expenditure*, which is shown in Table 137. Because the Wald test and all individual z-statistics (not shown here) are not statistically significant, the PDRE2 model is not shown here. Hence, the null hypothesis, $H1a_0$, could not be tested for manufacture of machinery and equipment n.e.c..

The PCRE2 model focuses on the relationship between process innovation and *internal R&D expenditure*, which is shown in Table 137. In this model, independent variables except *HHI* are not statistically significant at 10% level. Hence, the null hypothesis, $H3a_0$, is not rejected. *HHI* is statistically significant at the 1% level. It means, *ceteris paribus*, that an increase in *HHI* of 0.01, on average, leads to an increase of 224.9 in the likelihood of occurrence of process innovation.

Regression results of PDRE3 and PCRE3 models include coefficient, p-value, and average marginal effect, which are shown in Table 138. These models analyze the effect of *external R&D expenditure* on the probability of product and process innovations, respectively.

Table 138: Regression Results of PDRE3 and PCRE3 Models – C-28

Variable Name	PDRE3			PCRE3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpD</i>				-0.0229	0.253	-0.0068
<i>rdperint</i>				0.5017	0.582	0.1482
<i>IntoverD</i>				0.1865	0.037 **	0.0551
<i>HHI</i>				760.64	0.002 ***	224.63
<i>phd_ma</i>				-0.0083	0.725	-0.0025
<i>ipicsec</i>				-0.0059	0.141	-0.0018

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE3: Wald $\chi^2(6)=5.88$ Prob > $\chi^2=0.4364$

For PCRE3: Wald $\chi^2(6)=25.36$ Prob > $\chi^2=0.0003$

The PDRE3 model focuses on the relationship between product innovation and *external R&D expenditure*, which is shown in Table 138. Because the Wald test and 5 of 6 individual z-statistics (not shown here) are not statistically significant, the PDRE3 model is not shown here. Hence, the null hypothesis, $H1b_0$, could not be tested for manufacture of machinery and equipment n.e.c..

The PCRE3 model focuses on the relationship between process innovation and *external R&D expenditure*, which is shown in Table 138. In this model, independent variables except *turnover* and *HHI* are not statistically significant at 10% level. Hence, the null hypothesis, $H3b_0$, is not rejected. *Turnover* and *HHI* are statistically significant at the 5% and 1% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.51 percent in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 224.63 in the likelihood of occurrence of process innovation.

Regression results of PDRE4 and PCRE4 models include coefficient, p-value, and average marginal effect, which are shown in Table 139. These models analyze the effect of *external-domestic R&D expenditure* on the probability of product and process innovations, respectively.

Table 139: Regression Results of PDRE4 and PCRE4 Models – C-28

Variable Name	PDRE4			PCRE4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpdomD</i>				-0.0278	0.228	-0.0082
<i>rdperint</i>				0.5181	0.575	0.1529
<i>IntoverD</i>				0.1882	0.034 **	0.0556
<i>HHI</i>				763.82	0.002 ***	225.46
<i>phd_ma</i>				-0.0084	0.721	-0.0025
<i>ipicsec</i>				-0.0060	0.135	-0.0018

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE4: Wald chi2(6)=5.84 Prob > chi2=0.4408

For PCRE4: Wald chi2(6)=25.36 Prob > chi2=0.0003

The PDRE4 model focuses on the relationship between product innovation and *external-domestic R&D expenditure*, which is shown in Table 139. Because the Wald test and 5 of 6 individual z-statistics (not shown here) are not statistically significant, the PDRE4 model is not shown here. Hence, the null hypothesis, $H1c_0$, could not be tested for manufacture of machinery and equipment n.e.c..

The PCRE4 model focuses on the relationship between process innovation and *external-domestic R&D expenditure*, which is shown in Table 139. In this model, independent variables except *turnover* and *HHI* are not statistically significant at 10% level. Hence, the null hypothesis, $H3c_0$, is not rejected. *Turnover* and *HHI* are statistically significant at the 5% and 1% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.56 percent in the likelihood of occurrence of process innovation.

- An increase in *HHI* of 0.01, on average, leads to an increase of 225.46 in the likelihood of occurrence of process innovation.

Regression results of PDRE5 and PCRE5 models include coefficient, p-value, and average marginal effect, which are shown in Table 140. These models analyze the effect of *external-foreign R&D expenditure* on the probability of product and process innovations, respectively.

Table 140: Regression Results of PDRE5 and PCRE5 Models – C-28

Variable Name	PDRE5			PCRE5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpforD</i>				0.0146	0.198	0.0043
<i>rdperint</i>				0.4431	0.608	0.1297
<i>IntoverD</i>				0.1744	0.057 **	0.0510
<i>HHI</i>				768.63	0.002 ***	224.94
<i>phd_ma</i>				-0.0076	0.761	-0.0022
<i>ipicsec</i>				-0.0061	0.144	-0.0018

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE5: Wald chi2(6)=6.28 Prob > chi2=0.3929

For PCRE5: Wald chi2(6)=27.41 Prob > chi2=0.0001

The PDRE5 model focuses on the relationship between product innovation and *external-foreign R&D expenditure*, which is shown in Table 140. Because the Wald test and 5 of 6 individual z-statistics (not shown here) are not statistically significant, the PDRE5 model is not shown here. Hence, the null hypothesis, $H1d_0$, could not be tested for manufacture of machinery and equipment n.e.c..

The PCRE5 model focuses on the relationship between process innovation and *external-foreign R&D expenditure*, which is shown in Table 140. In this model, independent variables except *turnover* and *HHI* are not statistically significant at 10% level. Hence, the null hypothesis, $H3c_0$, is not rejected. *Turnover* and *HHI* are statistically significant at the 5% and 1% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.11 percent in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 224.94 in the likelihood of occurrence of process innovation.

Regression results of PDRI1 and PCRI1 models include coefficient, p-value, and average marginal effect, which are shown in Table 141. These models analyze the effect of *total R&D intensity* on the probability of product and process innovations, respectively.

Table 141: Regression Results of PDRI1 and PCRI1 Models – C-28

Variable Name	PDRI1			PCRI1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>totrdint</i>				-0.1672	0.717	-0.0491
<i>rdperint</i>				0.5384	0.628	0.1581
<i>IntoverD</i>				0.1742	0.054 **	0.0511
<i>HHI</i>				762.87	0.002 ***	224.03
<i>phd_ma</i>				-0.0067	0.785	-0.0020
<i>ipicsec</i>				-0.0060	0.147	-0.0018

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI1: Wald $\chi^2(6)=6.10$ Prob > $\chi^2=0.4121$

For PCRI1: Wald $\chi^2(6)=25.19$ Prob > $\chi^2=0.0003$

The PDRI1 model focuses on the relationship between product innovation and *total R&D intensity*, which is shown in Table 141. Because the Wald test and 5 of 6 individual z-statistics (not shown here) are not statistically significant, the PDRI1 model is not shown here. Hence, the null hypothesis, H_{20} , could not be tested for manufacture of machinery and equipment n.e.c..

The PCRI1 model focuses on the relationship between process innovation and *total R&D intensity*, which is shown in Table 141. In this model, independent variables except *turnover* and *HHI* are not statistically significant at 10% level. Hence, the null hypothesis, H_{40} , is not rejected. *Turnover* and *HHI* are statistically significant at the 5% and 1% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.11 percent in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 224.03 in the likelihood of occurrence of process innovation.

Regression results of PDRI2 and PCRI2 models include coefficient, p-value, and average marginal effect, which are shown in Table 142. These models analyze the

effect of *internal R&D intensity* on the probability of product and process innovations, respectively.

Table 142: Regression Results of PDRI2 and PCRI2 Models – C-28

Variable Name	PDRI2			PCRI2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>intrdint</i>				-0.6402	0.405	-0.1879
<i>rdperint</i>				0.6960	0.564	0.2043
<i>IntoverD</i>				0.1650	0.065 *	0.0484
<i>HHI</i>				755.54	0.003 ***	221.79
<i>phd_ma</i>				-0.0041	0.856	-0.0012
<i>ipicsec</i>				-0.0059	0.153	-0.0017

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI2: Wald $\chi^2(6)=5.23$ Prob > $\chi^2=0.5145$

For PCRI2: Wald $\chi^2(6)=26.47$ Prob > $\chi^2=0.0002$

The PDRI2 model focuses on the relationship between product innovation and *internal R&D intensity*, which is shown in Table 142. Because the Wald test and 5 of 6 individual z-statistics (not shown here) are not statistically significant, the PDRI2 model is not shown here. Hence, the null hypothesis, $H2a_0$, could not be tested for manufacture of machinery and equipment n.e.c..

The PCRI2 model focuses on the relationship between process innovation and *internal R&D intensity*, which is shown in Table 142. In this model, independent variables except *turnover* and *HHI* are not statistically significant at 10% level. Hence, the null hypothesis, $H4a_0$, is not rejected. *Turnover* and *HHI* are statistically significant at the 10% and 1% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.84 percent in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 221.79 in the likelihood of occurrence of process innovation.

Regression results of PDRI3 and PCRI3 models include coefficient, p-value, and average marginal effect, which are shown in Table 143. These models analyze the effect of *external R&D intensity* on the probability of product and process innovations, respectively.

Table 143: Regression Results of PDRI3 and PCRI3 Models – C-28

Variable Name	PDRI3			PCRI3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extrdint</i>	12.652	0.005 ***	4.0482	0.8692	0.200	0.2545
<i>rdperint</i>	0.9928	0.158	0.3177	0.3408	0.703	0.0998
<i>IntoverD</i>	0.1321	0.077 *	0.0423	0.1773	0.052 *	0.0519
<i>HHI</i>	306.90	0.226	98.200	763.60	0.002 ***	223.61
<i>phd_ma</i>	-0.0057	0.664	-0.0018	-0.0069	0.784	-0.0020
<i>ipicsec</i>	-0.0040	0.195	-0.0013	-0.0061	0.145	-0.0018

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI3: Wald chi2(6)=14.78 Prob > chi2=0.0220

For PCRI3: Wald chi2(6)=29.53 Prob > chi2=0.0000

The PDRI3 model focuses on the relationship between product innovation and *external R&D intensity*, which is shown in Table 143. In this model, independent variables except *external R&D intensity* and *turnover* are not statistically significant at 10% level. *External R&D intensity* is statistically significant at 1% level. Hence, the null hypothesis, $H2b_0$, is rejected. *Turnover* is statistically significant at the 10% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external R&D intensity*, on average, leads to an increase of 4.05 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.23 percent in the likelihood of occurrence of product innovation.

The PCRI3 model focuses on the relationship between process innovation and *external R&D intensity*, which is shown in Table 143. In this model, independent variables except *turnover* and *HHI* are not statistically significant at 10% level. Hence, the null hypothesis, $H4b_0$, is not rejected. *Turnover* and *HHI* are statistically significant at the 10% and 1% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.19 percent in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 223.61 in the likelihood of occurrence of process innovation.

Regression results of PDRI4 and PCRI4 models include coefficient, p-value, and average marginal effect, which are shown in Table 144. These models analyze the effect of *external-domestic R&D intensity* on the probability of product and process innovations, respectively.

Table 144: Regression Results of PDRI4 and PCRI4 Models – C-28

Variable Name	PDRI4			PCRI4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extdomrdint</i>	14.43	0.007 ***	4.6300	0.7351	0.279	0.2154
<i>rdperint</i>	0.993	0.157	0.3185	0.3524	0.696	0.1032
<i>IntoverD</i>	0.134	0.074 *	0.0429	0.1772	0.052 *	0.0519
<i>HHI</i>	305.25	0.229	97.948	764.61	0.002 ***	224.00
<i>phd_ma</i>	-0.006	0.672	-0.0018	-0.0070	0.783	-0.0020
<i>ipicsec</i>	-0.004	0.197	-0.0013	-0.0061	0.145	-0.0018

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI4: Wald chi2(6)=14.54 Prob > chi2=0.0241

For PCRI4: Wald chi2(6)=28.06 Prob > chi2=0.0001

The PDRI4 model focuses on the relationship between product innovation and *external-domestic R&D intensity*, which is shown in Table 144. In this model, independent variables except *external-domestic R&D intensity* and *turnover* are not statistically significant at 10% level. *external-domestic R&D intensity* is statistically significant at 1% level. Hence, the null hypothesis, $H2c_0$, is rejected. *Turnover* is statistically significant at the 10% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external-domestic R&D intensity*, on average, leads to an increase of 4.63 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.29 percent in the likelihood of occurrence of product innovation.

The PCRI4 model focuses on the relationship between process innovation and *external-domestic R&D intensity*, which is shown in Table 144. In this model, independent variables except *turnover* and *HHI* are not statistically significant at 10% level. Hence, the null hypothesis, $H4c_0$, is not rejected. *Turnover* and *HHI* are

statistically significant at the 10% and 1% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.19 percent in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 224.00 in the likelihood of occurrence of process innovation.

Regression results of PDRI5 and PCRI5 models include coefficient, p-value, and average marginal effect, which are shown in Table 145. These models analyze the effect of *external-foreign R&D intensity* on the probability of product and process innovations, respectively.

Table 145: Regression Results of PDRI5 and PCRI5 Models – C-28

Variable Name	PDRI5			PCRI5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extfrgrdint</i>	2.6163	0.000 ***	0.8435	4.7192	0.000 ***	1.3833
<i>rdperint</i>	1.0916	0.112	0.3519	0.4350	0.612	0.1275
<i>IntoverD</i>	0.1265	0.091 *	0.0408	0.1771	0.053 *	0.0519
<i>HHI</i>	307.86	0.224	99.252	763.23	0.002 ***	223.72
<i>phd_ma</i>	-0.0057	0.667	-0.0018	-0.0074	0.770	-0.0022
<i>ipicsec</i>	-0.0039	0.198	-0.0013	-0.0061	0.144	-0.0018

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI5: Wald chi2(6)=171.03 Prob > chi2=0.0001

For PCRI5: Wald chi2(6)=147.71 Prob > chi2=0.0000

The PDRI5 model focuses on the relationship between product innovation and *external-foreign R&D intensity*, which is shown in Table 145. In this model, independent variables except *external-foreign R&D intensity* and *turnover* are not statistically significant at 10% level. *external-foreign R&D intensity* is statistically significant at 1% level. Hence, the null hypothesis, H_{2d_0} , is rejected. *Turnover* is statistically significant at the 10% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external-foreign R&D intensity*, on average, leads to an increase of 0.84 in the likelihood of occurrence of product innovation.

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.08 percent in the likelihood of occurrence of product innovation.

The PCRI5 model focuses on the relationship between process innovation and *external-foreign R&D intensity*, which is shown in Table 145. In this model, independent variables except *external-foreign R&D intensity*, *turnover*, and *HHI* are not statistically significant at 10% level. *External-foreign R&D intensity* is statistically significant at 1% level. Hence, the null hypothesis, $H4d_0$, is rejected. *Turnover* and *HHI* are statistically significant at the 10% and 1% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external-foreign R&D intensity*, on average, leads to an increase of 1.38 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.19 percent in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 223.72 in the likelihood of occurrence of process innovation.

According to the analysis of the manufacture of machinery and equipment n.e.c., there are many findings in terms of product innovation. These are:

- PDRE models are not statistically significant according to the Wald test.
- R&D intensity variables such as external, external-domestic, and external-foreign are statistically significant and have positive effect on the likelihood of occurrence of product innovation in Turkish manufacturing industry. The most effective one is *external-domestic R&D intensity*.
- The other independent variables are interpreted by focusing on the PDRE1 and PDRI1 models. Because these models cover *total R&D expenditures*. According to the PDRE1 model and the PDRI1 model are not statistically significant according to the Wald test.

According to the analysis of the manufacture of machinery and equipment n.e.c., there are many findings in terms of process innovation. These are:

- R&D expenditure variables (PCRE models) are not statistically significant at 10% level.
- R&D intensity variables (PCRI models) except external-foreign are not statistically significant at 10% level. *External-foreign R&D intensity* has positive effect on the likelihood of occurrence of process innovation.
- The other independent variables are interpreted by focusing on the PCRE1 and PCRI1 models. Because these models cover *total R&D expenditures*. According to the PCRE1 model, *HHI* is statistically significant and has positive effect on the likelihood of occurrence of process innovation. According to the PCRI1 model, *turnover* and *HHI* are statistically significant, and they have positive effect on the likelihood of occurrence of process innovation. It means that more *turnover* and more concentrated machinery and equipment n.e.c. market increase the likelihood of occurrence of process innovation.

Results of the analyses are also viewed by comparing product and process innovation in terms of manufacture of machinery and equipment n.e.c.. These are:

- External and external-domestic R&D intensities affect only the likelihood of occurrence of product innovation positively.
- The impact of *external-foreign R&D intensity* on the likelihood of occurrence of process innovation is greater than its impact on the likelihood of occurrence of product innovation.

4.2.2.12. Manufacture of Motor Vehicles, Trailers and Semi-Trailers, C-29 by NACE Rev. 2

Firms that are engaged in R&D in manufacture of motor vehicles, trailers and semi-trailers are analyzed with twenty models such as 10 product innovation models and 10 process innovation models.

Regression results of PDRE1 and PCRE1 models include coefficient, p-value, and average marginal effect, which are shown in Table 146. These models analyze the effect of *total R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE1 model focuses on the relationship between product innovation and *total R&D expenditure*, which is shown in Table 146. In this model, independent variables except *total R&D expenditure* and the *number of highly educated R&D personnel* are not statistically significant at 10% level. *Total R&D expenditure* and the *number of highly educated R&D personnel* are statistically significant at 10% level. Hence, the null hypothesis, $H1_0$, is rejected. There are many results of this model, *ceteris paribus*, such as:

- A 1 percent increase in the value of *total R&D expenditure*, on average, leads to an increase of 5.82 percent in the likelihood of occurrence of product innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.015 in the likelihood of occurrence of product innovation.

Table 146: Regression Results of PDRE1 and PCRE1 Models – C-29

Variable Name	PDRE1			PCRE1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntrdexpD</i>	0.2068	0.073 *	0.0582	0.2557	0.008 ***	0.0621
<i>rdperint</i>	-0.8238	0.634	-0.2320	-1.6876	0.323	-0.4097
<i>IntoverD</i>	-0.0477	0.697	-0.0134	-0.0489	0.673	-0.0119
<i>HHI</i>	-2.3510	0.898	-0.6621	28.577	0.101	6.9374
<i>phd_ma</i>	0.0378	0.057 *	0.0106	0.0058	0.492	0.0014
<i>ipicsec</i>	-0.0011	0.704	0.0582	0.0030	0.324	0.0007

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE1: Wald $\chi^2(6)=21.34$ Prob > $\chi^2=0.0016$

For PCRE1: Wald $\chi^2(6)=23.22$ Prob > $\chi^2=0.0007$

The PCRE1 model focuses on the relationship between process innovation and *total R&D expenditure*, which is shown in Table 146. In this model, independent variables except *total R&D expenditure* are not statistically significant at 10% level. *Total R&D expenditure* is statistically significant at 1% level. Hence, the null

hypothesis, $H3_0$, is rejected. It means that a 1 percent increase in the value of *total R&D expenditure*, on average, leads to an increase of 6.21 percent in the likelihood of occurrence of process innovation.

Regression results of PDRE2 and PCRE2 models include coefficient, p-value, and average marginal effect, which are shown in Table 147. These models analyze the effect of *internal R&D expenditure* on the probability of product and process innovations, respectively.

Table 147: Regression Results of PDRE2 and PCRE2 Models – C-29

Variable Name	PDRE2			PCRE2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntintrdexpD</i>	0.2087	0.073 *	0.0588	0.2544	0.010 **	0.0618
<i>rdperint</i>	-0.8560	0.625	-0.2411	-1.7271	0.320	-0.4198
<i>IntoverD</i>	-0.0488	0.690	-0.0138	-0.0492	0.674	-0.0120
<i>HHI</i>	-3.3925	0.852	-0.9557	27.305	0.116	6.6374
<i>phd_ma</i>	0.0374	0.057 *	0.0105	0.0061	0.467	0.0015
<i>ipicsec</i>	-0.0012	0.677	-0.0003	0.0028	0.350	0.0007

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE2: Wald $\chi^2(6)=21.50$ Prob > $\chi^2=0.0015$

For PCRE2: Wald $\chi^2(6)=23.19$ Prob > $\chi^2=0.0007$

The PDRE2 model focuses on the relationship between product innovation and *internal R&D expenditure*, which is shown in Table 147. In this model, independent variables except *internal R&D expenditure* and the *number of highly educated R&D personnel* are not statistically significant at 10% level. *Internal R&D expenditure* and the *number of highly educated R&D personnel* are statistically significant at 10% level. Hence, the null hypothesis, $H1a_0$, is rejected. There are many results of this model, *ceteris paribus*, such as:

- A 1 percent increase in the value of *internal R&D expenditure*, on average, leads to an increase of 5.88 percent in the likelihood of occurrence of product innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.011 in the likelihood of occurrence of product innovation.

The PCRE2 model focuses on the relationship between process innovation and *internal R&D expenditure*, which is shown in Table 147. In this model, independent variables except *internal R&D expenditure* are not statistically significant at 10% level. *Internal R&D expenditure* is statistically significant at 1% level. Hence, the null hypothesis, $H3a_0$, is rejected. It means that a 1 percent increase in the value of *internal R&D expenditure*, on average, leads to an increase of 6.18 percent in the likelihood of occurrence of process innovation.

Regression results of PDRE3 and PCRE3 models include coefficient, p-value, and average marginal effect, which are shown in Table 148. These models analyze the effect of *external R&D expenditure* on the probability of product and process innovations, respectively.

Table 148: Regression Results of PDRE3 and PCRE3 Models – C-29

Variable Name	PDRE3			PCRE3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpD</i>	0.0272	0.095 *	0.0078	0.0287	0.060 *	0.0072
<i>rdperint</i>	1.0806	0.484	0.3111	0.7802	0.569	0.1952
<i>IntoverD</i>	0.0912	0.376	0.0262	0.1499	0.101	0.0375
<i>HHI</i>	-0.6872	0.970	-0.1979	30.153	0.077 *	7.5458
<i>phd_ma</i>	0.0477	0.020 **	0.0137	0.0098	0.458	0.0025
<i>ipicsec</i>	0.00005	0.986	0.0000	0.0039	0.175	0.0010

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE3: Wald $\chi^2(6)=23.74$ Prob > $\chi^2=0.0006$

For PCRE3: Wald $\chi^2(6)=16.75$ Prob > $\chi^2=0.0102$

The PDRE3 model focuses on the relationship between product innovation and *external R&D expenditure*, which is shown in Table 148. In this model, independent variables except *external R&D expenditure* and the *number of highly educated R&D personnel* are not statistically significant at 10% level. *External R&D expenditure* and the *number of highly educated R&D personnel* are statistically significant at the 10% and 5% level, respectively. Hence, the null hypothesis, $H1b_0$, is rejected. There are many results of this model, *ceteris paribus*, such as:

- A 1 percent increase in the value of *external R&D expenditure*, on average, leads to an increase of 0.78 percent in the likelihood of occurrence of product innovation.

- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.014 in the likelihood of occurrence of product innovation.

The PCRE3 model focuses on the relationship between process innovation and *external R&D expenditure*, which is shown in Table 148. In this model, independent variables except *external R&D expenditure* and *HHI* are not statistically significant at 10% level. *External R&D expenditure* is statistically significant at the 10% level. Hence, the null hypothesis, $H3b_0$, is rejected. There are many results of this model, *ceteris paribus*, such as:

- A 1 percent increase in the value of *external R&D expenditure*, on average, leads to an increase of 0.72 percent in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 7.55 in the likelihood of occurrence of process innovation.

Regression results of PDRE4 and PCRE4 models include coefficient, p-value, and average marginal effect, which are shown in Table 149. These models analyze the effect of *external-domestic R&D expenditure* on the probability of product and process innovations, respectively.

Table 149: Regression Results of PDRE4 and PCRE4 Models – C-29

Variable Name	PDRE4			PCRE4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpdomD</i>	0.0215	0.192	0.0062	0.0293	0.060 *	0.0073
<i>rdperint</i>	1.0274	0.504	0.2966	0.6739	0.627	0.1685
<i>IntoverD</i>	0.0945	0.359	0.0273	0.1499	0.104	0.0375
<i>HHI</i>	-1.0422	0.955	-0.3009	30.240	0.081 *	7.5600
<i>phd_ma</i>	0.0472	0.021 **	0.0136	0.0104	0.436	0.0026
<i>ipicsec</i>	-0.0001	0.958	0.0000	0.0038	0.195	0.0010

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE4: Wald $\chi^2(6) = 22.43$ Prob > $\chi^2 = 0.0010$

For PCRE4: Wald $\chi^2(6) = 16.14$ Prob > $\chi^2 = 0.0130$

The PDRE4 model focuses on the relationship between product innovation and *external-domestic R&D expenditure*, which is shown in Table 149. In this model, independent variables except the *number of highly educated R&D personnel* are not

statistically significant at 10% level. Hence, the null hypothesis, $H1c_0$, is not rejected. The *number of highly educated R&D personnel* is statistically significant at the 5% level. It means that a unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.014 in the likelihood of occurrence of product innovation.

The PCRE4 model focuses on the relationship between process innovation and *external-domestic R&D expenditure*, which is shown in Table 149. In this model, independent variables except *external-domestic R&D expenditure* and *HHI* are not statistically significant at 10% level. *External-domestic R&D expenditure* is statistically significant at the 10% level. Hence, the null hypothesis, $H3c_0$, is rejected. There are many results of this model, *ceteris paribus*, such as:

- A 1 percent increase in the value of *external-domestic R&D expenditure*, on average, leads to an increase of 0.73 percent in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 7.56 in the likelihood of occurrence of process innovation.

Regression results of PDRE5 and PCRE5 models include coefficient, p-value, and average marginal effect, which are shown in Table 150. These models analyze the effect of *external-foreign R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE5 model focuses on the relationship between product innovation and *external-foreign R&D expenditure*, which is shown in Table 150. In this model, independent variables except *external-foreign R&D expenditure* and the *number of highly educated R&D personnel* are not statistically significant at 10% level. *External-foreign R&D expenditure* is statistically significant at the 10% level. Hence, the null hypothesis, $H1d_0$, is rejected. The *number of highly educated R&D personnel* is statistically significant at the 5% level. There are many results of this model, *ceteris paribus*, such as:

- A 1 percent increase in the value of *external-foreign R&D expenditure*, on average, leads to an increase of 2 percent in the likelihood of occurrence of product innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.013 in the likelihood of occurrence of product innovation.

Table 150: Regression Results of PDRE5 and PCRE5 Models – C-29

Variable Name	PDRE5			PCRE5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpforD</i>	0.0694	0.088 *	0.0200	0.0636	0.327	0.0160
<i>rdperint</i>	1.0623	0.483	0.3057	0.5931	0.665	0.1492
<i>IntoverD</i>	0.0836	0.394	0.0241	0.1355	0.133	0.0341
<i>HHI</i>	-3.8375	0.829	-1.1042	26.681	0.092 *	6.7116
<i>phd_ma</i>	0.0465	0.014 **	0.0134	0.0118	0.382	0.0030
<i>ipicsec</i>	0.0001	0.980	0.00002	0.0041	0.151	0.0010

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE5: Wald $\chi^2(6)=22.38$ Prob > $\chi^2=0.0010$

For PCRE5: Wald $\chi^2(6)=16.24$ Prob > $\chi^2=0.0125$

The PCRE5 model focuses on the relationship between process innovation and *external-foreign R&D expenditure*, which is shown in Table 150. In this model, independent variables except *HHI* are not statistically significant at 10% level. Hence, the null hypothesis, $H3d_0$, is not rejected. *HHI* is statistically significant at 10% level. It means, *ceteris paribus*, that an increase in *HHI* of 0.01, on average, leads to an increase of 6.71 in the likelihood of occurrence of process innovation.

Regression results of PDRI1 and PCRI1 models include coefficient, p-value, and average marginal effect, which are shown in Table 151. These models analyze the effect of *total R&D intensity* on the probability of product and process innovations, respectively.

The PDRI1 model focuses on the relationship between product innovation and *total R&D intensity*, which is shown in Table 151. In this model, independent variables except the *number of highly educated R&D personnel* are not statistically significant at 10% level. Hence, the null hypothesis, $H2_0$, is not rejected. The *number of highly educated R&D personnel* is statistically significant at 5% level. It means that a unit

increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.014 in the likelihood of occurrence of product innovation.

Table 151: Regression Results of PDRI1 and PCRI1 Models – C-29

Variable Name	PDRI1			PCRI1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>totrdint</i>	2.3721	0.307	0.6867	5.0588	0.104	1.2616
<i>rdperint</i>	0.0794	0.963	0.0230	-1.2068	0.490	-0.3009
<i>IntoverD</i>	0.1144	0.283	0.0331	0.1792	0.067 *	0.0447
<i>HHI</i>	-3.8238	0.832	-1.1070	26.304	0.106	6.5597
<i>phd_ma</i>	0.0472	0.016 **	0.0137	0.0123	0.437	0.0031
<i>ipicsec</i>	-0.0006	0.821	-0.0002	0.0031	0.278	0.0008

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI1: Wald chi2(6)=17.63 Prob > chi2=0.0072

For PCRI1: Wald chi2(6)=18.19 Prob > chi2=0.0058

The PCRI1 model focuses on the relationship between process innovation and *total R&D intensity*, which is shown in Table 151. In this model, independent variables except *turnover* are not statistically significant at the 10% level. Hence, the null hypothesis, H_{40} , is not rejected. *Turnover* is statistically significant at the 10% level. It means that that a 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.27 percent in the likelihood of occurrence of process innovation.

Regression results of PDRI2 and PCRI2 models include coefficient, p-value, and average marginal effect, which are shown in Table 152. These models analyze the effect of *internal R&D intensity* on the probability of product and process innovations, respectively.

Table 152: Regression Results of PDRI2 and PCRI2 Models – C-29

Variable Name	PDRI2			PCRI2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>intrdint</i>	2.4356	0.306	0.7052	4.6724	0.115	1.1676
<i>rdperint</i>	0.0567	0.974	0.0164	-1.1268	0.520	-0.2816
<i>IntoverD</i>	0.1147	0.283	0.0332	0.1769	0.070 *	0.0442
<i>HHI</i>	-4.0913	0.821	-1.1846	25.797	0.114	6.4464
<i>phd_ma</i>	0.0470	0.017 **	0.0136	0.0124	0.424	0.0031
<i>ipicsec</i>	-0.0006	0.818	-0.0002	0.0031	0.277	0.0008

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI2: Wald chi2(6)=17.65 Prob > chi2=0.0072

For PCRI2: Wald chi2(6)=18.00 Prob > chi2=0.0062

The PDRI2 model focuses on the relationship between product innovation and *internal R&D intensity*, which is shown in Table 152. In this model, independent variables except the *number of highly educated R&D personnel* are not statistically significant at 10% level. Hence, the null hypothesis, $H2a_0$, is not rejected. The *number of highly educated R&D personnel* is statistically significant at 5% level. It means that a unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.014 in the likelihood of occurrence of product innovation.

The PCRI2 model focuses on the relationship between process innovation and *internal R&D intensity*, which is shown in Table 152. In this model, independent variables except *turnover* are not statistically significant at the 10% level. Hence, the null hypothesis, $H4a_0$, is not rejected. *Turnover* is statistically significant at the 10% level. It means that that a 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.42 percent in the likelihood of occurrence of process innovation.

Regression results of PDRI3 and PCRI3 models include coefficient, p-value, and average marginal effect, which are shown in Table 153. These models analyze the effect of *external R&D intensity* on the probability of product and process innovations, respectively.

Table 153: Regression Results of PDRI3 and PCRI3 Models – C-29

Variable Name	PDRI3			PCRI3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extrdint</i>	0.0328	0.999	0.0095	35.211	0.001 ***	8.8120
<i>rdperint</i>	1.0683	0.481	0.3102	0.6848	0.618	0.1714
<i>lntoverD</i>	0.1005	0.313	0.0292	0.1564	0.080 *	0.0391
<i>HHI</i>	-3.0663	0.864	-0.8905	30.468	0.071 *	7.6250
<i>phd_ma</i>	0.0467	0.016 **	0.0136	0.0114	0.355	0.0029
<i>ipicsec</i>	-0.0003	0.911	-0.0001	0.0038	0.186	0.0010

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI3: Wald $\chi^2(6) = 17.87$ Prob > $\chi^2 = 0.0066$

For PCRI3: Wald $\chi^2(6) = 27.98$ Prob > $\chi^2 = 0.0001$

The PDRI3 model focuses on the relationship between product innovation and *external R&D intensity*, which is shown in Table 153. In this model, independent variables except the *number of highly educated R&D personnel* are not statistically significant at 10% level. Hence, the null hypothesis, $H2b_0$, is not rejected. The *number*

of highly educated R&D personnel is statistically significant at 5% level. It means that a unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.014 in the likelihood of occurrence of product innovation.

The PCRI3 model focuses on the relationship between process innovation and *external R&D intensity*, which is shown in Table 153. In this model, independent variables except *external R&D intensity*, *turnover*, and *HHI* are not statistically significant at the 10% level. *External R&D intensity* is statistically significant at the 1% level. Hence, the null hypothesis, $H4b_0$, is rejected. *Turnover* and *HHI* are statistically significant at the 10% level. There are many results of this model, *ceteris paribus*, such as:

- A 1 percent increase in the value of *external R&D intensity*, on average, leads to an increase of 8.81 percent in the likelihood of occurrence of process innovation.
- A 1 percent increase in the value of *turnover*, on average, leads to an increase of 3.91 percent in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 7.63 in the likelihood of occurrence of process innovation.

Regression results of PDRI4 and PCRI4 models include coefficient, p-value, and average marginal effect, which are shown in Table 154. These models analyze the effect of *external-domestic R&D intensity* on the probability of product and process innovations, respectively.

The PDRI4 model focuses on the relationship between product innovation and *external-domestic R&D intensity*, which is shown in Table 154. In this model, independent variables except the *number of highly educated R&D personnel* are not statistically significant at 10% level. Hence, the null hypothesis, $H2c_0$, is not rejected. The *number of highly educated R&D personnel* is statistically significant at 5% level. It means that a unit increase in the value of the *number of highly educated R&D*

personnel, on average, leads to an increase of 0.014 in the likelihood of occurrence of product innovation.

The PCRI4 model focuses on the relationship between process innovation and *external-domestic R&D intensity*, which is shown in Table 154. In this model, independent variables except *external-domestic R&D intensity*, *turnover*, and *HHI* are not statistically significant at the 10% level. *External-domestic R&D intensity* is statistically significant at the 1% level. Hence, the null hypothesis, $H4c_0$, is rejected. *Turnover* and *HHI* are statistically significant at the 10% level. There are many results of this model, *ceteris paribus*, such as:

- A 1 percent increase in the value of *external-domestic R&D intensity*, on average, leads to an increase of 7.43 percent in the likelihood of occurrence of process innovation.
- A 1 percent increase in the value of *turnover*, on average, leads to an increase of 3.97 percent in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 7.51 in the likelihood of occurrence of process innovation.

Table 154: Regression Results of PDRI4 and PCRI4 Models – C-29

Variable Name	PDRI4			PCRI4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extdomrdint</i>	-11.706	0.609	-3.3996	29.565	0.004 ***	7.4252
<i>rdperint</i>	1.0507	0.488	0.3051	0.6651	0.629	0.1670
<i>IntoverD</i>	0.0979	0.324	0.0284	0.1581	0.077 *	0.0397
<i>HHI</i>	-4.3945	0.808	-1.2762	29.892	0.075 *	7.5072
<i>phd_ma</i>	0.0464	0.016 **	0.0135	0.0114	0.366	0.0029
<i>ipicsec</i>	-0.0003	0.914	-0.0001	0.0037	0.195	0.0009

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI4: Wald $\chi^2(6)=18.21$ Prob > $\chi^2=0.0057$

For PCRI4: Wald $\chi^2(6)=23.87$ Prob > $\chi^2=0.0006$

Regression results of PDRI5 and PCRI5 models include coefficient, p-value, and average marginal effect, which are shown in Table 155. These models analyze the effect of *external-foreign R&D intensity* on the probability of product and process innovations, respectively.

The PDRI5 model focuses on the relationship between product innovation and *external-foreign R&D intensity*, which is shown in Table 155. In this model, independent variables except *external-foreign R&D intensity* and the *number of highly educated R&D personnel* are not statistically significant at 10% level. *External-foreign R&D intensity* is statistically significant at 10% level. Hence, the null hypothesis, $H2d_0$, is rejected. The *number of highly educated R&D personnel* is statistically significant at 5% level. There are many results of this model, *ceteris paribus*, such as:

- A 1 percent increase in the value of *external-foreign R&D intensity*, on average, leads to an increase of 209.9 percent in the likelihood of occurrence of product innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.014 in the likelihood of occurrence of product innovation.

The PCRI5 model focuses on the relationship between process innovation and *external-foreign R&D intensity*, which is shown in Table 155. In this model, independent variables are not statistically significant at the 10% level. Hence, the null hypothesis, $H4d_0$, is not rejected.

Table 155: Regression Results of PDRI5 and PCRI5 Models – C-29

Variable Name	PDRI5			PCRI5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extfrgrdint</i>	730.76	0.073 *	209.90	1036.1	0.471	257.93
<i>rdperint</i>	1.0369	0.499	0.2978	0.7085	0.611	0.1764
<i>lntoverD</i>	0.0821	0.402	0.0236	0.1412	0.108	0.0352
<i>HHI</i>	-3.9410	0.828	-1.1320	27.209	0.092	6.7735
<i>phd_ma</i>	0.0475	0.014 **	0.0136	0.0108	0.370	0.0027
<i>ipicsec</i>	0.0001	0.977	0.00002	0.0042	0.151	0.0010

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI5: Wald $\chi^2(6) = 22.76$ Prob > $\chi^2 = 0.0009$

For PCRI5: Wald $\chi^2(6) = 15.88$ Prob > $\chi^2 = 0.0144$

According to the analysis of the manufacture of motor vehicles, trailers and semi-trailers, there are many findings in terms of product innovation. These are:

- R&D expenditure variables except external-domestic are statistically significant and have positive effect on the likelihood of occurrence of

product innovation in Turkish manufacturing industry. The most effective one is *internal R&D expenditure*.

- R&D intensity variables except external-foreign are not statistically significant at 10% level. *External-foreign R&D intensity* has positive effect on the likelihood of occurrence of product innovation in Turkish manufacturing industry.
- The other independent variables are interpreted by focusing on the PDRE1 and PDRI1 models. Because these models cover *total R&D expenditures*. According to the PDRE1 model and the PDRI1 model, the *number of highly educated R&D personnel* is statistically significant and has positive effect on the likelihood of occurrence of product innovation. It means that more highly educated R&D personnel increases the likelihood of occurrence of product innovation in the manufacture of motor vehicles, trailers and semi-trailers.

According to the analysis of the manufacture of motor vehicles, trailers and semi-trailers, there are many findings in terms of process innovation. These are:

- R&D expenditure variables except external-foreign are statistically significant and have positive effects on the likelihood of occurrence of process innovation. The most effective one is *total R&D expenditure*.
- R&D intensity variables except external and external-foreign are not statistically significant at 10% level. External and external-foreign R&D intensities have positive effect on the likelihood of occurrence of process innovation.
- The other independent variables are interpreted by focusing on the PCRE1 and PCRI1 models. Because these models cover *total R&D expenditures*. According to the PCRE1 model, other independent variables are not statistically significant at 10% level. According to the PCRI1 model, *turnover* is statistically significant and has positive effect on the likelihood of occurrence of process innovation. It means that more *turnover* increases

the likelihood of occurrence of process innovation in the manufacture of motor vehicles, trailers and semi-trailers.

Results of the analyses are also viewed by comparing product and process innovation in terms of manufacture of motor vehicles, trailers and semi-trailers. These are:

- The impact of *total* and *internal R&D expenditure* on the likelihood of occurrence of process innovation are greater than its impact on the likelihood of occurrence of product innovation.
- The impact of *external R&D expenditure* on the likelihood of occurrence of product innovation is greater than its impact on the likelihood of occurrence of process innovation.
- *External-domestic R&D expenditure* affects only the likelihood of occurrence of process innovation positively.
- *External-foreign R&D expenditure* affects only the likelihood of occurrence of product innovation positively.
- *External* and *external-domestic R&D intensity* affect only the likelihood of occurrence of process innovation positively.
- *External-foreign R&D intensity* affects only the likelihood of occurrence of product innovation positively.

In this chapter, firms that engaged in R&D in Turkish manufacturing industry are analyzed to reveal the effect of independent variables on the likelihood of occurrence of product and process innovations, from the two perspectives such as analysis of the industry by section C (as a whole) and by division (manufacturing industry separately), except manufacture of tobacco products that does not have any R&D activities in the panel data. In detail, firstly, descriptive statistics is presented. Then, the results of the analysis are interpreted in the shadow of theoretical framework, research methodology, and research design. These results are reported by product innovation, process innovation, and by comparing product and process innovation. The results of the analyses in terms of product innovation are tabulated in Appendix 11.

The results of the analyses in terms of process innovation are tabulated in Appendix 12.

In the next chapter, firms that engaged in R&D in Turkish manufacturing industry are analyzed from the three perspectives by classifications in terms of TI, EII, and FS, to reveal the effect of independent variables on the likelihood of occurrence of product and process innovations.



CHAPTER FIVE

ANALYSIS OF TURKISH MANUFACTURING INDUSTRY BY CLASSIFICATIONS

In this dissertation, firms that engaged in R&D in Turkish manufacturing industry are analyzed from the five perspectives such as analysis of the industry by section C (as a whole), by division (manufacturing industry separately), and by classifications in terms of TI, EII, and FS, to reveal the effect of R&D expenditure and R&D intensity on the likelihood of occurrence of product and process innovations. To analyze these firms, twenty research models are used, which are product and process innovation models. Results of the analysis by these models are presented.

First three chapter focused on respectively theoretical framework regarding R&D and innovation, short history of Turkish economy and R&D statistics, and data and methodology.

The fourth chapter includes descriptive statistics about panel data and the results of the analysis of Turkish manufacturing industry by section C and division. Twelve divisions (twelve sectors) by NACE Rev. 2 2-digit are analyzed because of lack of observation numbers (number of firm). In other words, observation numbers as a cluster must be more than forty (Mancl and DeRouen, 2001).

In this chapter, firms that engaged in R&D in Turkish manufacturing industry are analyzed by classifications by TI, EII, and FS, to reveal the differences among the classes in terms of product and process innovation such as differences between HT and MHT, differences between HEI and MHEI, and differences between small size and medium size firms.

5.1. Turkish Manufacturing Industry Analysis – Technology Intensity (TI)

Technology intensity classification is used to analyze manufacturing industry in many studies such as Lee (2004) and Bhattacharya and Bloch (2004). Lee (2004)

showed that, in Malaysian manufacturing industry, firms in high-tech industries are more innovative than firms in low tech industries, but there is a contradiction. Bhattacharya and Bloch (2004) showed that, in Australian manufacturing industry, there are positive relationship between innovation and R&D intensity (R&D expenditure/sales) but there are differences between high tech and low-tech industries. So, in this dissertation, technology intensity classification is used to reveal differences by this classification in terms of likelihood of occurrence of innovation.

The analysis of all Turkish manufacturing industry by high-tech classification include all manufacturing industries, except manufacture of tobacco products. The classification by technology intensity includes High Technology (HT), Medium-High Technology (MHT), Medium-Low Technology (MLT), and Low Technology (LT).

5.1.1. High Technology Manufacturing Industries (HT)

Firms that are engaged in R&D activities in the high technology manufacturing industry are analyzed with twenty models such as 10 product innovation models and 10 process innovation models, which are shown in Table 3 that is in Chapter 3 and in Appendix 7, 8, 9, and 10.

Regression results of PDRE1 and PCRE1 models include coefficient, p-value, and average marginal effect, which are shown in Table 156. These models analyze the effect of *total R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE1 model focuses on the relationship between product innovation and *total R&D expenditure*, which is shown in Table 156. In this model, independent variables are not statistically significant at 10% level, except *HHI*. Hence, the null hypothesis, $H1_0$, is not rejected. *HHI* is statistically significant at the 1% level. It means, *ceteris paribus*, that an increase in *HHI* of 0.01, on average, leads to an increase of 1.43 in the likelihood of occurrence of product innovation.

The PCRE1 model focuses on the relationship between process innovation and *total R&D expenditure*, which is shown in Table 156. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity*,

turnover, and industrial production index by manufacturing industry. Hence, the null hypothesis, $H3_0$, is not rejected. *R&D personnel intensity*, *turnover*, and *industrial production index by manufacturing industry* are statistically significant at 10%, 1%, and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.18 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 7.14 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.13 percent in the likelihood of occurrence of process innovation.

Table 156: Regression Results of PDRE1 and PCRE1 Models – HT

Variable Name	PDRE1			PCRE1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>lntrdexpD</i>	0.0918	0.330	0.0255	-0.0246	0.683	-0.0073
<i>rdperint</i>	-0.1127	0.825	-0.0312	0.6139	0.093 *	0.1810
<i>lnloverD</i>	0.0706	0.459	0.0196	0.2421	0.005 ***	0.0714
<i>HHI</i>	5.1837	0.005 ***	1.4366	1.3694	0.431	0.4038
<i>phd_ma</i>	0.0001	0.827	0.00003	0.0013	0.405	0.0004
<i>ipicsec</i>	0.0015	0.480	0.0004	0.0043	0.036 **	0.0013

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE1: Wald $\chi^2(6) = 22.56$ Prob > $\chi^2 = 0.0010$

For PCRE1: Wald $\chi^2(6) = 22.96$ Prob > $\chi^2 = 0.0008$

Regression results of PDRE2 and PCRE2 models include coefficient, p-value, and average marginal effect, which are shown in Table 157. These models analyze the effect of *internal R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE1 model focuses on the relationship between product innovation and *internal R&D expenditure*, which is shown in Table 157. In this model, independent variables are not statistically significant at 10% level, except *HHI*. Hence, the null hypothesis, $H1a_0$, is not rejected. *HHI* is statistically significant at the 1% level. It

means, *ceteris paribus*, that an increase in *HHI* of 0.01, on average, leads to an increase of 1.44 in the likelihood of occurrence of product innovation.

Table 157: Regression Results of PDRE2 and PCRE2 Models – HT

Variable Name	PDRE2			PCRE2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntintrdexpD</i>	0.0818	0.361	0.0228	-0.0426	0.465	-0.0126
<i>rdperint</i>	-0.0953	0.850	-0.0265	0.6653	0.071 *	0.1963
<i>IntoverD</i>	0.0767	0.408	0.0213	0.2569	0.003 ***	0.0758
<i>HHI</i>	5.1622	0.005 ***	1.4359	1.3651	0.432	0.4028
<i>phd_ma</i>	0.0002	0.766	0.0000	0.0015	0.363	0.0004
<i>ipicsec</i>	0.0014	0.492	0.0004	0.0043	0.036 **	0.0013

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE2: Wald chi2(6)=22.57 Prob > chi2=0.0010

For PCRE2: Wald chi2(6)=23.17 Prob > chi2=0.0007

The PCRE1 model focuses on the relationship between process innovation and *internal R&D expenditure*, which is shown in Table 157. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity*, *turnover*, and *industrial production index by manufacturing industry*. Hence, the null hypothesis, H_{3a_0} , is not rejected. *R&D personnel intensity*, *turnover*, and *industrial production index by manufacturing industry* are statistically significant at 10%, 1%, and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.2 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 7.58 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.13 percent in the likelihood of occurrence of process innovation.

Regression results of PDRE3 and PCRE3 models include coefficient, p-value, and average marginal effect, which are shown in Table 158. These models analyze the effect of *external R&D expenditure* on the probability of product and process innovations, respectively.

Table 158: Regression Results of PDRE3 and PCRE3 Models – HT

Variable Name	PDRE3			PCRE3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpD</i>	0.0312	0.096 *	0.0086	0.0154	0.368	0.0045
<i>rdperint</i>	0.0827	0.867	0.0229	0.5107	0.154	0.1494
<i>IntoverD</i>	0.1315	0.056 *	0.0364	0.2151	0.002 ***	0.0629
<i>HHI</i>	5.2971	0.004 ***	1.4648	1.4180	0.417	0.4148
<i>phd_ma</i>	0.0005	0.457	0.0001	0.0011	0.402	0.0003
<i>ipicsec</i>	0.0019	0.350	0.0005	0.0047	0.029 **	0.0014

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE3: Wald chi2(6)=27.60 Prob > chi2=0.0001

For PCRE3: Wald chi2(6)=26.60 Prob > chi2=0.0002

The PDRE3 model focuses on the relationship between product innovation and *external R&D expenditure*, which is shown in Table 158. In this model, independent variables are not statistically significant at the 10% level, except *external R&D expenditure*, *turnover*, and *HHI*. *External R&D expenditure* is statistically significant at the 10% level. Hence, the null hypothesis, $H1b_0$, is rejected. *Turnover* and *HHI* are statistically significant at the 10% and 1% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *external R&D expenditure*, on average, leads to an increase of 0.86 percent in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 3.64 percent in the likelihood of occurrence of product innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 1.47 in the likelihood of occurrence of product innovation.

The PCRE3 model focuses on the relationship between process innovation and *external R&D expenditure*, which is shown in Table 158. In this model, independent variables are not statistically significant at 10% level, except *turnover* and *industrial production index by manufacturing industry*. Hence, the null hypothesis, $H3b_0$, is not rejected. The *turnover* and *industrial production index by manufacturing industry* are statistically significant at 1% and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 6.29 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.13 percent in the likelihood of occurrence of process innovation.

Regression results of PDRE4 and PCRE4 models include coefficient, p-value, and average marginal effect, which are shown in Table 159. These models analyze the effect of *external-domestic R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE4 model focuses on the relationship between product innovation and *external-domestic R&D expenditure*, which is shown in Table 159. In this model, independent variables are not statistically significant at the 10% level, except *turnover* and *HHI*. Hence, the null hypothesis, $H1c_0$, is not rejected. *Turnover* and *HHI* are statistically significant at the 10% and 1% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 3.67 percent in the likelihood of occurrence of product innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 1.46 in the likelihood of occurrence of product innovation.

The PCRE4 model focuses on the relationship between process innovation and *external-domestic R&D expenditure*, which is shown in Table 159. In this model, independent variables are not statistically significant at 10% level, except *turnover* and *industrial production index by manufacturing industry*. Hence, the null hypothesis, $H3c_0$, is not rejected. The *turnover* and *industrial production index by manufacturing industry* are statistically significant at 1% and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 6.41 percent in the likelihood of occurrence of process innovation.

- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.13 percent in the likelihood of occurrence of process innovation.

Table 159: Regression Results of PDRE4 and PCRE4 Models – HT

Variable Name	PDRE4			PCRE4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpdomD</i>	0.0273	0.164	0.0076	0.0083	0.609	0.0024
<i>rdperint</i>	0.0775	0.873	0.0216	0.5249	0.142	0.1542
<i>IntoverD</i>	0.1317	0.054 *	0.0367	0.2181	0.002 ***	0.0641
<i>HHI</i>	5.2313	0.004 ***	1.4576	1.3820	0.427	0.4060
<i>phd_ma</i>	0.0005	0.444	0.0001	0.0011	0.428	0.0003
<i>ipicsec</i>	0.0017	0.399	0.0005	0.0045	0.033 **	0.0013

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE4: Wald chi2(6)=26.02 Prob > chi2=0.0002

For PCRE4: Wald chi2(6)=25.27 Prob > chi2=0.0003

Regression results of PDRE5 and PCRE5 models include coefficient, p-value, and average marginal effect, which are shown in Table 160. These models analyze the effect of *external-foreign R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE5 model focuses on the relationship between product innovation and *external-foreign R&D expenditure*, which is shown in Table 160. In this model, independent variables are not statistically significant at the 10% level, except *turnover* and *HHI*. Hence, the null hypothesis, $H1d_0$, is not rejected. *Turnover* and *HHI* are statistically significant at the 10% and 1% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 3.64 percent in the likelihood of occurrence of product innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 1.48 in the likelihood of occurrence of product innovation.

The PCRE5 model focuses on the relationship between process innovation and *external-foreign R&D expenditure*, which is shown in Table 160. In this model, independent variables are not statistically significant at 10% level, except *turnover* and *industrial production index by manufacturing industry*. Hence, the null hypothesis,

$H3d_0$, is not rejected. The *turnover* and *industrial production index by manufacturing industry* are statistically significant at 1% and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 6.34 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.13 percent in the likelihood of occurrence of process innovation.

Table 160: Regression Results of PDRE5 and PCRE5 Models – HT

Variable Name	PDRE5			PCRE5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpforD</i>	0.0311	0.369	0.0087	0.0177	0.623	0.0052
<i>rdperint</i>	0.0844	0.861	0.0236	0.5225	0.149	0.1533
<i>IntoverD</i>	0.1299	0.057 *	0.0364	0.2160	0.002 ***	0.0634
<i>HHI</i>	5.2741	0.004 ***	1.4784	1.4521	0.405	0.4260
<i>phd_ma</i>	0.0004	0.521	0.0001	0.0010	0.485	0.0003
<i>ipicsec</i>	0.0016	0.415	0.0004	0.0045	0.033 **	0.0013

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE5: Wald $\chi^2(6)=24.96$ Prob > $\chi^2=0.0003$

For PCRE5: Wald $\chi^2(6)=23.69$ Prob > $\chi^2=0.0006$

Regression results of PDRI1 and PCRI1 models include coefficient, p-value, and average marginal effect, which are shown in Table 161. These models analyze the effect of *total R&D intensity* on the probability of product and process innovations, respectively.

The PDRI1 model focuses on the relationship between product innovation and *total R&D intensity*, which is shown in Table 161. In this model, independent variables are not statistically significant at the 10% level, except *turnover* and *HHI*. Hence, the null hypothesis, $H2_0$, is not rejected. *Turnover* and *HHI* are statistically significant at the 5% and 1% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.23 percent in the likelihood of occurrence of product innovation.

- An increase in *HHI* of 0.01, on average, leads to an increase of 1.46 in the likelihood of occurrence of product innovation.

Table 161: Regression Results of PDRI1 and PCRI1 Models – HT

Variable Name	PDRI1			PCRI1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>totrdint</i>	1.3883	0.142	0.3855	1.7516	0.047 **	0.5056
<i>rdperint</i>	-0.1687	0.760	-0.0468	0.2039	0.608	0.0589
<i>IntoverD</i>	0.1525	0.021 **	0.0423	0.2391	0.001 ***	0.0690
<i>HHI</i>	5.2529	0.005 ***	1.4584	1.3465	0.444	0.3887
<i>phd_ma</i>	0.0001	0.867	0.00002	0.0000	1.000	0.0000
<i>ipicsec</i>	0.0015	0.478	0.0004	0.0047	0.032 **	0.0014

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI1: Wald $\chi^2(6) = 22.58$ Prob > $\chi^2 = 0.0010$

For PCRI1: Wald $\chi^2(6) = 25.75$ Prob > $\chi^2 = 0.0002$

The PCRI1 model focuses on the relationship between process innovation and *total R&D intensity*, which is shown in Table 161. In this model, independent variables are not statistically significant at 10% level, except *total R&D intensity*, *turnover*, and *industrial production index by manufacturing industry*. *Total R&D intensity* is statistically significant at 5% level. Hence, the null hypothesis, H_{40} , is rejected. The *turnover* and *industrial production index by manufacturing industry* are statistically significant at 1% and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *total R&D intensity*, on average, leads to an increase of 0.51 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 6.9 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.14 percent in the likelihood of occurrence of process innovation.

Regression results of PDRI2 and PCRI2 models include coefficient, p-value, and average marginal effect, which are shown in Table 162. These models analyze the effect of *internal R&D intensity* on the probability of product and process innovations, respectively.

The PDRI2 model focuses on the relationship between product innovation and *internal R&D intensity*, which is shown in Table 162. In this model, independent variables are not statistically significant at the 10% level, except *turnover* and *HHI*. Hence, the null hypothesis, $H2a_0$, is not rejected. *Turnover* and *HHI* are statistically significant at the 5% and 1% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.11 percent in the likelihood of occurrence of product innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 1.45 in the likelihood of occurrence of product innovation.

Table 162: Regression Results of PDRI2 and PCRI2 Models – HT

Variable Name	PDRI2			PCRI2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>intrdint</i>	1.4597	0.138	0.4072	1.3221	0.142	0.3854
<i>rdperint</i>	-0.1788	0.747	-0.0499	0.2884	0.466	0.0841
<i>IntoverD</i>	0.1475	0.025 **	0.0411	0.2297	0.001 ***	0.0670
<i>HHI</i>	5.2091	0.005 ***	1.4531	1.3592	0.437	0.3962
<i>phd_ma</i>	0.0001	0.804	0.00004	0.0003	0.782	0.0001
<i>ipicsec</i>	0.0014	0.498	0.0004	0.0045	0.035 **	0.0013

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI2: Wald $\chi^2(6) = 22.12$ Prob > $\chi^2 = 0.0012$

For PCRI2: Wald $\chi^2(6) = 24.17$ Prob > $\chi^2 = 0.0005$

The PCRI2 model focuses on the relationship between process innovation and *total R&D intensity*, which is shown in Table 162. In this model, independent variables are not statistically significant at 10% level, except *turnover* and *industrial production index by manufacturing industry*. Hence, the null hypothesis, $H4a_0$, is not rejected. The *turnover* and *industrial production index by manufacturing industry* are statistically significant at 1% and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 6.7 percent in the likelihood of occurrence of process innovation.

- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.13 percent in the likelihood of occurrence of process innovation.

Regression results of PDRI3 and PCRI3 models include coefficient, p-value, and average marginal effect, which are shown in Table 163. These models analyze the effect of *external R&D intensity* on the probability of product and process innovations, respectively.

The PDRI3 model focuses on the relationship between product innovation and *external R&D intensity*, which is shown in Table 163. In this model, independent variables are not statistically significant at the 10% level, except *turnover* and *HHI*. Hence, the null hypothesis, $H2b_0$, is not rejected. *Turnover* and *HHI* are statistically significant at the 5% and 1% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 3.93 percent in the likelihood of occurrence of product innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 1.47 in the likelihood of occurrence of product innovation.

Table 163: Regression Results of PDRI3 and PCRI3 Models – HT

Variable Name	PDRI3			PCRI3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extrdint</i>	0.8697	0.187	0.2454	3.7980	0.000 ***	1.1027
<i>rdperint</i>	0.0888	0.853	0.0250	0.5438	0.135	0.1579
<i>lntoverD</i>	0.1394	0.034 **	0.0393	0.2326	0.001 ***	0.0675
<i>HHI</i>	5.2130	0.005 ***	1.4710	1.4528	0.408	0.4218
<i>phd_ma</i>	0.0005	0.423	0.0001	0.0009	0.506	0.0002
<i>ipicsec</i>	0.0014	0.504	0.0004	0.0046	0.031 **	0.0013

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI3: Wald $\chi^2(6) = 21.96$ Prob > $\chi^2 = 0.0012$

For PCRI3: Wald $\chi^2(6) = 31.40$ Prob > $\chi^2 = 0.0000$

The PCRI3 model focuses on the relationship between process innovation and *external R&D intensity*, which is shown in Table 163. In this model, independent variables are not statistically significant at 10% level, except *external R&D intensity*, *turnover*, and *industrial production index by manufacturing industry*. *External R&D*

intensity is statistically significant at 1% level. Hence, the null hypothesis, $H4b_0$, is rejected. The *turnover* and *industrial production index by manufacturing industry* are statistically significant at 1% and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external R&D intensity*, on average, leads to an increase of 1.1 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 6.75 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.13 percent in the likelihood of occurrence of process innovation.

Regression results of PDRI4 and PCRI4 models include coefficient, p-value, and average marginal effect, which are shown in Table 164. These models analyze the effect of *external-domestic R&D intensity* on the probability of product and process innovations, respectively.

The PDRI4 model focuses on the relationship between product innovation and *external-domestic R&D intensity*, which is shown in Table 164. In this model, independent variables are not statistically significant at the 10% level, except *turnover* and *HHI*. Hence, the null hypothesis, $H2c_0$, is not rejected. *Turnover* and *HHI* are statistically significant at the 5% and 1% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 3.92 percent in the likelihood of occurrence of product innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 1.47 in the likelihood of occurrence of product innovation.

The PCRI4 model focuses on the relationship between process innovation and *external-domestic R&D intensity*, which is shown in Table 164. In this model, independent variables are not statistically significant at 10% level, except *external-domestic R&D intensity*, *turnover*, and *industrial production index by manufacturing*

industry. *External-domestic R&D intensity* is statistically significant at 1% level. Hence, the null hypothesis, $H4c_0$, is rejected. The *turnover* and *industrial production index by manufacturing industry* are statistically significant at 1% and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external-domestic R&D intensity*, on average, leads to an increase of 1.06 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 6.73 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.13 percent in the likelihood of occurrence of process innovation.

Table 164: Regression Results of PDRI4 and PCRI4 Models – HT

Variable Name	PDRI4			PCRI4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extdomrdint</i>	0.8288	0.162	0.2340	3.6339	0.000 ***	1.0568
<i>rdperint</i>	0.0882	0.854	0.0249	0.5435	0.134	0.1580
<i>IntoverD</i>	0.1390	0.035 **	0.0392	0.2316	0.001 ***	0.0673
<i>HHI</i>	5.2034	0.005 ***	1.4690	1.4315	0.414	0.4163
<i>phd_ma</i>	0.0005	0.420	0.0001	0.0009	0.495	0.0003
<i>ipicsec</i>	0.0014	0.507	0.0004	0.0046	0.032 **	0.0013

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI4: Wald $\chi^2(6) = 22.08$ Prob > $\chi^2 = 0.0012$

For PCRI4: Wald $\chi^2(6) = 29.26$ Prob > $\chi^2 = 0.0001$

Regression results of PDRI5 and PCRI5 models include coefficient, p-value, and average marginal effect, which are shown in Table 165. These models analyze the effect of *external-foreign R&D intensity* on the probability of product and process innovations, respectively.

The PDRI5 model focuses on the relationship between product innovation and *external-foreign R&D intensity*, which is shown in Table 165. In this model, independent variables are not statistically significant at the 10% level, except *turnover* and *HHI*. Hence, the null hypothesis, $H2d_0$, is not rejected. *Turnover* and *HHI* are

statistically significant at the 5% and 1% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 3.91 percent in the likelihood of occurrence of product innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 1.48 in the likelihood of occurrence of product innovation.

Table 165: Regression Results of PDRI5 and PCRI5 Models – HT

Variable Name	PDRI5			PCRI5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extfrgrdint</i>	4.6154	0.538	1.3043	21.436	0.003 ***	6.2422
<i>rdperint</i>	0.0912	0.849	0.0258	0.5691	0.127	0.1657
<i>IntoverD</i>	0.1385	0.035 **	0.0391	0.2290	0.001 ***	0.0667
<i>HHI</i>	5.2488	0.004 ***	1.4833	1.5684	0.370	0.4567
<i>phd_ma</i>	0.0005	0.422	0.0001	0.0012	0.484	0.0003
<i>ipicsec</i>	0.0013	0.505	0.0004	0.0046	0.032 **	0.0013

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI5: Wald chi2(6)=21.37 Prob > chi2=0.0016

For PCRI5: Wald chi2(6)=26.95 Prob > chi2=0.0001

The PCRI5 model focuses on the relationship between process innovation and *external-foreign R&D intensity*, which is shown in Table 165. In this model, independent variables are not statistically significant at 10% level, except *external-foreign R&D intensity*, *turnover*, and *industrial production index by manufacturing industry*. *External-foreign R&D intensity* is statistically significant at 1% level. Hence, the null hypothesis, H_0 , is rejected. The *turnover* and *industrial production index by manufacturing industry* are statistically significant at 1% and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external-foreign R&D intensity*, on average, leads to an increase of 6.24 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 6.67 percent in the likelihood of occurrence of process innovation.

- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.13 percent in the likelihood of occurrence of process innovation.

According to the analysis of Turkish manufacturing industry with high technology, there are many findings in terms of product innovation. These are:

- R&D expenditure variables except *external R&D expenditure* are not statistically significant at 10% level. *External R&D expenditure* has positive effect on the likelihood of occurrence of product innovation. It means that more *external R&D expenditure* increases the likelihood of occurrence of product innovation.
- R&D intensity variables are not statistically significant at 10% level.
- According to PDRE1 model, *HHI* is statistically significant and has positive effect on the likelihood of occurrence of product innovation. According to PDRI1 model, *turnover* and *HHI* are statistically significant and have positive effect on the likelihood of occurrence of product innovation. It means that more concentrated manufacturing industry with high-tech and more *turnover* increase the likelihood of occurrence of product innovation.

According to the analysis of Turkish manufacturing industry with high technology, there are many findings in terms of process innovation. These are:

- R&D expenditure variables are not statistically significant at 10% level.
- R&D intensity variables except internal are statistically significant and they have positive effect on the likelihood of occurrence of process innovation. It means that more of these intensities (total, external, external-domestic, external-foreign) increase the likelihood of occurrence of process innovation. The most effective one is *external-foreign R&D intensity*.
- According to PCRE1 model, *R&D personnel intensity*, *turnover*, and *industrial production index by manufacturing industry* are statistically

significant and have positive effect on the likelihood of occurrence of process innovation. According to PCRI1 model, *turnover* and *industrial production index by manufacturing industry* are statistically significant and have positive effect on the likelihood of occurrence of process innovation. It means that more R&D intensity, more *turnover*, and more *industrial production index by manufacturing industry* increase the likelihood of occurrence of process innovation.

Results of the analyses are also viewed by comparing product and process innovation in terms of Turkish manufacturing industry with high technology. These are:

- *External R&D expenditure* affects only the likelihood of occurrence of product innovation positively.
- *Total, external, external-domestic, and external-foreign R&D intensity* affect only the likelihood of occurrence of process innovation positively.

5.1.2. Medium-High Technology Manufacturing Industries (MHT)

Firms that are engaged in R&D in the medium-high technology manufacturing industry are analyzed with twenty models such as 10 product innovation models and 10 process innovation models, which are shown in Table 3 that is in Chapter 3 and in Appendix 7, 8, 9, and 10.

Regression results of PDRE1 and PCRE1 models include coefficient, p-value, and average marginal effect, which are shown in Table 166. These models analyze the effect of *total R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE1 model focuses on the relationship between product innovation and *total R&D expenditure*, which is shown in Table 166. In this model, independent variables are not statistically significant at 10% level, except *total R&D expenditure*. *Total R&D expenditure* is statistically significant at the 5% level. Hence, the null hypothesis, $H1_0$, is rejected. It means, *ceteris paribus*, that 1 percent increase in the

value of *total R&D expenditure*, on average, leads to an increase of 3.1 percent in the likelihood of occurrence of product innovation.

Table 166: Regression Results of PDRE1 and PCRE1 Models – MHT

Variable Name	PDRE1			PCRE1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntrdexpD</i>	0.1047	0.027 **	0.0310	0.0979	0.037 **	0.0275
<i>rdperint</i>	0.3608	0.458	0.1066	0.1930	0.710	0.0542
<i>IntoverD</i>	0.0275	0.614	0.0081	0.0979	0.075 *	0.0275
<i>HHI</i>	-2.9658	0.201	-0.8765	3.1761	0.169	0.8917
<i>phd_ma</i>	0.0117	0.288	0.0035	0.0003	0.899	0.0001
<i>ipicsec</i>	-0.00002	0.987	-0.00001	0.0036	0.006 ***	0.0010

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE1: Wald chi2(6)=24.03 Prob > chi2=0.0005

For PCRE1: Wald chi2(6)=47.06 Prob > chi2=0.0000

The PCRE1 model focuses on the relationship between process innovation and *total R&D expenditure*, which is shown in Table 166. In this model, independent variables are not statistically significant at 10% level, except *total R&D expenditure*, *turnover*, and *industrial production index by manufacturing industry*. *Total R&D expenditure* is statistically significant at 5% level. Hence, the null hypothesis, H_{30} , is rejected. *Turnover* and *industrial production index by manufacturing industry* are statistically significant at 10% and 1% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *total R&D expenditure*, on average, leads to an increase of 2.75 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 2.75 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.1 percent in the likelihood of occurrence of process innovation.

Regression results of PDRE2 and PCRE2 models include coefficient, p-value, and average marginal effect, which are shown in Table 167. These models analyze the

effect of *internal R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE2 model focuses on the relationship between product innovation and *internal R&D expenditure*, which is shown in Table 167. In this model, independent variables are not statistically significant at 10% level, except *internal R&D expenditure*. *internal R&D expenditure* is statistically significant at the 5% level. Hence, the null hypothesis, $H1a_0$, is rejected. It means, *ceteris paribus*, that 1 percent increase in the value of *total R&D expenditure*, on average, leads to an increase of 3.38 percent in the likelihood of occurrence of product innovation.

Table 167: Regression Results of PDRE2 and PCRE2 Models – MHT

Variable Name	PDRE2			PCRE2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntintrdexpD</i>	0.1146	0.016 **	0.0338	0.1035	0.029 **	0.0290
<i>rdperint</i>	0.3089	0.519	0.0912	0.1629	0.751	0.0457
<i>IntoverD</i>	0.0207	0.704	0.0061	0.0937	0.089 *	0.0263
<i>HHI</i>	-3.0490	0.189	-0.8998	3.1552	0.172	0.8851
<i>phd_ma</i>	0.0112	0.290	0.0033	0.0002	0.934	0.00005
<i>ipicsec</i>	0.0000	0.969	-0.00001	0.0036	0.006 ***	0.0010

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE2: Wald $\chi^2(6)=24.85$ Prob > $\chi^2=0.0004$

For PCRE2: Wald $\chi^2(6)=47.41$ Prob > $\chi^2=0.0000$

The PCRE2 model focuses on the relationship between process innovation and *internal R&D expenditure*, which is shown in Table 167. In this model, independent variables are not statistically significant at 10% level, except *internal R&D expenditure*, *turnover*, and *industrial production index by manufacturing industry*. *Internal R&D expenditure* is statistically significant at 5% level. Hence, the null hypothesis, $H3_0$, is rejected. *Turnover* and *industrial production index by manufacturing industry* are statistically significant at 10% and 1% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *total R&D expenditure*, on average, leads to an increase of 2.9 percent in the likelihood of occurrence of process innovation.

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 2.63 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.1 percent in the likelihood of occurrence of process innovation.

Regression results of PDRE3 and PCRE3 models include coefficient, p-value, and average marginal effect, which are shown in Table 168. These models analyze the effect of *external R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE3 model focuses on the relationship between product innovation and *external R&D expenditure*, which is shown in Table 168. In this model, independent variables are not statistically significant at the 10% level, except *R&D personnel intensity* and *turnover*. Hence, the null hypothesis, $H1b_0$, is not rejected. *R&D personnel intensity* and *turnover* are statistically significant at the 10% and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.27 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 2.77 percent in the likelihood of occurrence of product innovation.

Table 168: Regression Results of PDRE3 and PCRE3 Models – MHT

Variable Name	PDRE3			PCRE3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpD</i>	-0.0033	0.681	-0.0010	-0.0053	0.547	-0.0015
<i>rdperint</i>	0.8937	0.087 *	0.2665	0.6832	0.197	0.1949
<i>IntoverD</i>	0.0929	0.048 **	0.0277	0.1696	0.000 ***	0.0484
<i>HHI</i>	-2.1511	0.347	-0.6414	3.8857	0.083 *	1.1086
<i>phd_ma</i>	0.0195	0.156	0.0058	0.0022	0.485	0.0006
<i>ipicsec</i>	0.0002	0.878	0.0001	0.0038	0.002 ***	0.0011

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE3: Wald chi2(6)=16.95 Prob > chi2=0.0095

For PCRE3: Wald chi2(6)=39.17 Prob > chi2=0.0000

The PCRE3 model focuses on the relationship between process innovation and *external R&D expenditure*, which is shown in Table 168. In this model, independent variables are not statistically significant at 10% level, except *turnover*, *HHI*, and *industrial production index by manufacturing industry*. Hence, the null hypothesis, $H3b_0$, is not rejected. The *turnover*, *HHI*, and *industrial production index by manufacturing industry* are statistically significant at 1%, 10%, and 1% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.84 percent in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 1.11 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.11 percent in the likelihood of occurrence of process innovation.

Regression results of PDRE4 and PCRE4 models include coefficient, p-value, and average marginal effect, which are shown in Table 169. These models analyze the effect of *external-domestic R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE4 model focuses on the relationship between product innovation and *external-domestic R&D expenditure*, which is shown in Table 169. In this model, independent variables are not statistically significant at the 10% level, except *R&D personnel intensity* and *turnover*. Hence, the null hypothesis, $H1c_0$, is not rejected. *R&D personnel intensity* and *turnover* are statistically significant at the 10% and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.27 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 2.76 percent in the likelihood of occurrence of product innovation.

Table 169: Regression Results of PDRE4 and PCRE4 Models – MHT

Variable Name	PDRE4			PCRE4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpdomD</i>	-0.0023	0.780	-0.0007	-0.0062	0.506	-0.0018
<i>rdperint</i>	0.8943	0.087 *	0.2667	0.6872	0.196	0.1961
<i>IntoverD</i>	0.0926	0.049 **	0.0276	0.1697	0.000 ***	0.0484
<i>HHI</i>	-2.1586	0.344	-0.6437	3.8644	0.084 *	1.1026
<i>phd_ma</i>	0.0194	0.160	0.0058	0.0022	0.486	0.0006
<i>ipicsec</i>	0.0002	0.871	0.0001	0.0038	0.002 ***	0.0011

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE4: Wald chi2(6)=16.84 Prob > chi2=0.0099

For PCRE4: Wald chi2(6)=39.27 Prob > chi2=0.0000

The PCRE4 model focuses on the relationship between process innovation and *external-domestic R&D expenditure*, which is shown in Table 169. In this model, independent variables are not statistically significant at 10% level, except *turnover*, *HHI*, and *industrial production index by manufacturing industry*. Hence, the null hypothesis, $H3c_0$, is not rejected. The *turnover*, *HHI*, and *industrial production index by manufacturing industry* are statistically significant at 1%, 10%, and 1% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.84 percent in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 1.1 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.11 percent in the likelihood of occurrence of process innovation.

Regression results of PDRE5 and PCRE5 models include coefficient, p-value, and average marginal effect, which are shown in Table 170. These models analyze the effect of *external-foreign R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE5 model focuses on the relationship between product innovation and *external-foreign R&D expenditure*, which is shown in Table 170. In this model, independent variables are not statistically significant at the 10% level, except *R&D*

personnel intensity and *turnover*. Hence, the null hypothesis, $H1d_0$, is not rejected. *R&D personnel intensity* and *turnover* are statistically significant at the 10% and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.27 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 3.01 percent in the likelihood of occurrence of product innovation.

Table 170: Regression Results of PDRE5 and PCRE5 Models – MHT

Variable Name	PDRE5			PCRE5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpforD</i>	-0.0128	0.350	-0.0038	0.0205	0.150	0.0058
<i>rdperint</i>	0.8917	0.076 *	0.2679	0.6678	0.205	0.1896
<i>IntoverD</i>	0.1001	0.029 **	0.0301	0.1639	0.000 ***	0.0465
<i>HHI</i>	-2.1651	0.345	-0.6504	3.6945	0.098 *	1.0488
<i>phd_ma</i>	0.0163	0.197	0.0049	0.0020	0.490	0.0006
<i>ipicsec</i>	0.0003	0.813	0.0001	0.0039	0.002 ***	0.0011

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE5: Wald $\chi^2(6) = 17.80$ Prob > $\chi^2 = 0.0068$

For PCRE5: Wald $\chi^2(6) = 44.84$ Prob > $\chi^2 = 0.0000$

The PCRE5 model focuses on the relationship between process innovation and *external-foreign R&D expenditure*, which is shown in Table 170. In this model, independent variables are not statistically significant at 10% level, except *turnover*, *HHI*, and *industrial production index by manufacturing industry*. Hence, the null hypothesis, $H3d_0$, is not rejected. The *turnover*, *HHI*, and *industrial production index by manufacturing industry* are statistically significant at 1%, 10%, and 1% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.65 percent in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 1.05 in the likelihood of occurrence of process innovation.

- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.11 percent in the likelihood of occurrence of process innovation.

Regression results of PDRI1 and PCRI1 models include coefficient, p-value, and average marginal effect, which are shown in Table 171. These models analyze the effect *total R&D intensity* on the probability of product and process innovations, respectively.

The PDRI1 model focuses on the relationship between product innovation and *total R&D intensity*, which is shown in Table 171. In this model, independent variables are not statistically significant at the 10% level, except *turnover*. Hence, the null hypothesis, H_{20} , is not rejected. *Turnover* is statistically significant at the 10% level. It means, *ceteris paribus*, that a 1 percent increase in the value of *turnover*, on average, leads to an increase of 2.75 percent in the likelihood of occurrence of product innovation.

Table 171: Regression Results of PDRI1 and PCRI1 Models – MHT

Variable Name	PDRI1			PCRI1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>totrdint</i>	0.0428	0.897	0.0128	0.1147	0.724	0.0327
<i>rdperint</i>	0.8665	0.172	0.2583	0.6012	0.350	0.1713
<i>IntoverD</i>	0.0923	0.052 *	0.0275	0.1688	0.000 ***	0.0481
<i>HHI</i>	-2.1662	0.344	-0.6458	3.8015	0.090 *	1.0830
<i>phd_ma</i>	0.0192	0.161	0.0057	0.0021	0.495	0.0006
<i>ipicsec</i>	0.0002	0.876	0.0001	0.0038	0.002 ***	0.0011

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI1: Wald $\chi^2(6) = 19.06$ Prob > $\chi^2 = 0.0041$

For PCRI1: Wald $\chi^2(6) = 39.36$ Prob > $\chi^2 = 0.0000$

The PCRI1 model focuses on the relationship between process innovation and *total R&D intensity*, which is shown in Table 171. In this model, independent variables are not statistically significant at 10% level, except *turnover*, *HHI*, and *industrial production index by manufacturing industry*. Hence, the null hypothesis, H_{40} , is not rejected. The *turnover*, *HHI*, and *industrial production index by manufacturing industry* are statistically significant at 1%, 10%, and 1% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.81 percent in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 1.08 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.11 percent in the likelihood of occurrence of process innovation.

Regression results of PDRI2 and PCRI2 models include coefficient, p-value, and average marginal effect, which are shown in Table 172. These models analyze the effect *internal R&D intensity* on the probability of product and process innovations, respectively.

The PDRI2 model focuses on the relationship between product innovation and *internal R&D intensity*, which is shown in Table 172. In this model, independent variables are not statistically significant at the 10% level, except *turnover*. Hence, the null hypothesis, $H2a_0$, is not rejected. *Turnover* is statistically significant at the 10% level. It means, *ceteris paribus*, that a 1 percent increase in the value of *turnover*, on average, leads to an increase of 2.75 percent in the likelihood of occurrence of product innovation.

Table 172: Regression Results of PDRI2 and PCRI2 Models – MHT

Variable Name	PDRI2			PCRI2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>intrdint</i>	-0.0308	0.940	-0.0092	0.0798	0.841	0.0227
<i>rdperint</i>	0.9098	0.157	0.2714	0.6292	0.334	0.1793
<i>IntoverD</i>	0.0921	0.052 *	0.0275	0.1685	0.000 ***	0.0480
<i>HHI</i>	-2.1370	0.352	-0.6374	3.8114	0.090 *	1.0860
<i>phd_ma</i>	0.0192	0.160	0.0057	0.0021	0.492	0.0006
<i>ipicsec</i>	0.0002	0.865	0.0001	0.0038	0.002 ***	0.0011

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI2: Wald chi2(6)=20.51 Prob > chi2=0.0022

For PCRI2: Wald chi2(6)=39.52 Prob > chi2=0.0000

The PCRI2 model focuses on the relationship between process innovation and *internal R&D intensity*, which is shown in Table 172. In this model, independent variables are not statistically significant at 10% level, except *turnover*, *HHI*, and

industrial production index by manufacturing industry. Hence, the null hypothesis, $H4a_0$, is not rejected. The *turnover*, *HHI*, and *industrial production index by manufacturing industry* are statistically significant at 1%, 10%, and 1% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.8 percent in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 1.09 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.11 percent in the likelihood of occurrence of process innovation.

Regression results of PDRI3 and PCRI3 models include coefficient, p-value, and average marginal effect, which are shown in Table 173. These models analyze the effect *external R&D intensity* on the probability of product and process innovations, respectively.

The PDRI3 model focuses on the relationship between product innovation and *external R&D intensity*, which is shown in Table 173. In this model, independent variables are not statistically significant at the 10% level, except *turnover*. Hence, the null hypothesis, $H2b_0$, is not rejected. *Turnover* is statistically significant at the 10% level. It means, *ceteris paribus*, that a 1 percent increase in the value of *turnover*, on average, leads to an increase of 2.7 percent in the likelihood of occurrence of product innovation.

The PCRI3 model focuses on the relationship between process innovation and *external R&D intensity*, which is shown in Table 173. In this model, independent variables are not statistically significant at 10% level, except *turnover*, *HHI*, and *industrial production index by manufacturing industry*. Hence, the null hypothesis, $H4b_0$, is not rejected. The *turnover*, *HHI*, and *industrial production index by manufacturing industry* are statistically significant at 1%, 10%, and 1% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.78 percent in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 1.09 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.11 percent in the likelihood of occurrence of process innovation.

Table 173: Regression Results of PDRI3 and PCRI3 Models – MHT

Variable Name	PDRI3			PCRI3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extrdint</i>	1.5618	0.436	0.4650	0.7673	0.199	0.2186
<i>rdperint</i>	0.8439	0.123	0.2512	0.6303	0.248	0.1796
<i>IntoverD</i>	0.0907	0.060 *	0.0270	0.1679	0.000 ***	0.0478
<i>HHI</i>	-2.1095	0.355	-0.6280	3.8347	0.086 *	1.0925
<i>phd_ma</i>	0.0200	0.152	0.0060	0.0022	0.480	0.0006
<i>ipicsec</i>	0.0001	0.897	0.00004	0.0038	0.002 ***	0.0011

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI3: Wald chi2(6)=18.00 Prob > chi2=0.0062

For PCRI3: Wald chi2(6)=43.61 Prob > chi2=0.0000

Regression results of PDRI4 and PCRI4 models include coefficient, p-value, and average marginal effect, which are shown in Table 174. These models analyze the effect *external-domestic R&D intensity* on the probability of product and process innovations, respectively.

The PDRI4 model focuses on the relationship between product innovation and *external-domestic R&D intensity*, which is shown in Table 174. In this model, independent variables are not statistically significant at the 10% level, except *turnover*. Hence, the null hypothesis, $H2c_0$, is not rejected. *Turnover* is statistically significant at the 10% level. It means, *ceteris paribus*, that a 1 percent increase in the value of *turnover*, on average, leads to an increase of 2.7 percent in the likelihood of occurrence of product innovation.

The PCRI4 model focuses on the relationship between process innovation and *external-domestic R&D intensity*, which is shown in Table 174. In this model, independent variables are not statistically significant at 10% level, except *turnover*,

HHI, and *industrial production index by manufacturing industry*. Hence, the null hypothesis, $H4c_0$, is not rejected. The *turnover*, *HHI*, and *industrial production index by manufacturing industry* are statistically significant at 1%, 10%, and 1% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.78 percent in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 1.09 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.11 percent in the likelihood of occurrence of process innovation.

Table 174: Regression Results of PDRI4 and PCRI4 Models – MHT

Variable Name	PDRI4			PCRI4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extdomrdint</i>	0.7697	0.275	0.2292	0.5852	0.299	0.1667
<i>rdperint</i>	0.8554	0.120	0.2547	0.6380	0.244	0.1818
<i>IntoverD</i>	0.0906	0.060 *	0.0270	0.1679	0.000 ***	0.0478
<i>HHI</i>	-2.1172	0.354	-0.6304	3.8339	0.087 *	1.0924
<i>phd_ma</i>	0.0200	0.151	0.0060	0.0022	0.480	0.0006
<i>ipicsec</i>	0.0002	0.891	0.00005	0.0038	0.002 ***	0.0011

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI4: Wald $\chi^2(6) = 20.51$ Prob > $\chi^2 = 0.0022$

For PCRI4: Wald $\chi^2(6) = 42.27$ Prob > $\chi^2 = 0.0000$

Regression results of PDRI5 and PCRI5 models include coefficient, p-value, and average marginal effect, which are shown in Table 175. These models analyze the effect *external-foreign R&D intensity* on the probability of product and process innovations, respectively.

The PDRI5 model focuses on the relationship between product innovation and *external-foreign R&D intensity*, which is shown in Table 175. In this model, independent variables are not statistically significant at the 10% level, except *R&D personnel intensity* and *turnover*. Hence, the null hypothesis, $H2d_0$, is not rejected. *R&D personnel intensity* and *turnover* are statistically significant at the 10% and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.27 in the likelihood of occurrence of product innovation.
- A 1 percent increase in the value of *turnover*, on average, leads to an increase of 2.78 percent in the likelihood of occurrence of product innovation.

Table 175: Regression Results of PDRI5 and PCRI5 Models – MHT

Variable Name	PDRI5			PCRI5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extfrgrdint</i>	18.931	0.571	5.6451	5.1073	0.076 *	1.4546
<i>rdperint</i>	0.8887	0.087 *	0.2650	0.6706	0.201	0.1910
<i>IntoverD</i>	0.0933	0.048 **	0.0278	0.1679	0.000 ***	0.0478
<i>HHI</i>	-2.1900	0.338	-0.6531	3.8312	0.087 *	1.0912
<i>phd_ma</i>	0.0184	0.173	0.0055	0.0021	0.487	0.0006
<i>ipicsec</i>	0.0002	0.852	0.0001	0.0038	0.002 ***	0.0011

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI5: Wald chi2(6)=17.64 Prob > chi2=0.0072

For PCRI5: Wald chi2(6)=44.40 Prob > chi2=0.0000

The PCRI5 model focuses on the relationship between process innovation and *external-foreign R&D intensity*, which is shown in Table 175. In this model, independent variables are not statistically significant at 10% level, except *turnover*, *HHI*, and *industrial production index by manufacturing industry*. Hence, the null hypothesis, *H4c0*, is not rejected. The *turnover*, *HHI*, and *industrial production index by manufacturing industry* are statistically significant at 1%, 10%, and 1% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external-foreign R&D intensity*, on average, leads to an increase of 1.46 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.78 percent in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 1.09 in the likelihood of occurrence of process innovation.

- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.11 percent in the likelihood of occurrence of process innovation.

According to the analysis of Turkish manufacturing industry with medium-high technology, there are many findings in terms of product innovation. These are:

- R&D expenditure variables such as total and internal are statistically significant and they have positive effect on the likelihood of occurrence of product innovation. It means that more total and *internal R&D expenditures* increase the likelihood of occurrence of product innovation.
- R&D intensity variables are not statistically significant at 10% level.
- According to PDRE1 model, other independent variables are not statistically significant at 10% level. According to PDRI1 model, *turnover* is statistically significant and has positive effect on the likelihood of occurrence of product innovation. It means that more *turnover* increases the likelihood of occurrence of product innovation.

According to the analysis of Turkish manufacturing industry with medium-high technology, there are many findings in terms of process innovation. These are:

- R&D expenditure variables except total and internal are not statistically significant at 10% level. Total and *internal R&D expenditures* are statistically significant and have positive effect on the likelihood of occurrence of process innovation. It means that more total and *internal R&D expenditures* increase the likelihood of occurrence of process innovation. The most effective expenditure type is *internal R&D expenditure*.
- R&D intensity variables except external-foreign are not statistically significant at 10% level. *External-foreign R&D intensity* is statistically significant and has positive effect on the likelihood of occurrence of process innovation.

- According to PCRE1 model, *turnover* and *industrial production index by manufacturing industry* are statistically significant and have positive effects on the likelihood of occurrence of process innovation. According to PCRI1 model, *turnover*, *HHI*, and *industrial production index by manufacturing industry* are statistically significant and have positive effect on the likelihood of occurrence of process innovation. It means that more *turnover*, more concentrated MHT industries, and more *industrial production index by manufacturing industry* increase the likelihood of occurrence of process innovation.

Results of the analyses are also viewed by comparing product and process innovation in terms of Turkish manufacturing industry with medium-high technology. These are:

- The impact of *total* and *internal R&D expenditures* on the likelihood of occurrence of product innovation are greater than their impacts on the likelihood of occurrence of process innovation.
- *External-foreign R&D intensity* affects only the likelihood of occurrence of process innovation positively.

5.1.3. Medium-Low Technology Manufacturing Industries (MLT)

Firms that are engaged in R&D in the medium-low technology manufacturing industry are analyzed with twenty models such as 10 product innovation models and 10 process innovation models, which are shown in Table 3 that is in Chapter 3 and in Appendix 7, 8, 9, and 10.

Regression results of PDRE1 and PCRE1 models include coefficient, p-value, and average marginal effect, which are shown in Table 176. These models analyze the effect of *total R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE1 model focuses on the relationship between product innovation and *total R&D expenditure*, which is shown in Table 176. In this model, independent variables are not statistically significant at 10% level, except *total R&D expenditure*.

Total R&D expenditure is statistically significant at the 1% level. Hence, the null hypothesis, $H1_0$, is rejected. It means, *ceteris paribus*, that 1 percent increase in the value of *total R&D expenditure*, on average, leads to an increase of 6.96 percent in the likelihood of occurrence of product innovation.

Table 176: Regression Results of PDRE1 and PCRE1 Models – MLT

Variable Name	PDRE1			PCRE1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntrdexpD</i>	0.1945	0.000 ***	0.0696	0.1373	0.000 ***	0.0459
<i>rdperint</i>	-0.2498	0.392	-0.0893	0.0875	0.729	0.0293
<i>IntoverD</i>	-0.0247	0.604	-0.0088	0.0379	0.366	0.0127
<i>HHI</i>	0.3854	0.378	0.1379	0.4940	0.246	0.1652
<i>phd_ma</i>	-0.0172	0.115	-0.0062	0.0106	0.370	0.0035
<i>ipicsec</i>	0.0006	0.696	0.0002	0.0004	0.800	0.0001

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE1: Wald $\chi^2(6) = 39.37$ Prob > $\chi^2 = 0.0000$

For PCRE1: Wald $\chi^2(6) = 33.97$ Prob > $\chi^2 = 0.0000$

The PCRE1 model focuses on the relationship between process innovation and *total R&D expenditure*, which is shown in Table 176. In this model, independent variables are not statistically significant at 10% level, except *total R&D expenditure*. *Total R&D expenditure* is statistically significant at 1% level. Hence, the null hypothesis, $H3_0$, is rejected. It means, *ceteris paribus*, that 1 percent increase in the value of *total R&D expenditure*, on average, leads to an increase of 4.59 percent in the likelihood of occurrence of process innovation.

Regression results of PDRE2 and PCRE2 models include coefficient, p-value, and average marginal effect, which are shown in Table 177. These models analyze the effect of *internal R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE2 model focuses on the relationship between product innovation and *internal R&D expenditure*, which is shown in Table 177. In this model, independent variables are not statistically significant at 10% level, except *internal R&D expenditure*. *Internal R&D expenditure* is statistically significant at the 1% level. Hence, the null hypothesis, $H1a_0$, is rejected. It means, *ceteris paribus*, that 1 percent increase in the value of *total R&D expenditure*, on average, leads to an increase of 6.68 percent in the likelihood of occurrence of product innovation.

The PCRE2 model focuses on the relationship between process innovation and *internal R&D expenditure*, which is shown in Table 177. In this model, independent variables are not statistically significant at 10% level, except *internal R&D expenditure*. *Internal R&D expenditure* is statistically significant at 1% level. Hence, the null hypothesis, $H3a_0$, is rejected. It means, *ceteris paribus*, that 1 percent increase in the value of *total R&D expenditure*, on average, leads to an increase of 4.41 percent in the likelihood of occurrence of process innovation.

Table 177: Regression Results of PDRE2 and PCRE2 Models – MLT

Variable Name	PDRE2			PCRE2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntintrdexpD</i>	0.1864	0.000 ***	0.0668	0.1315	0.000 ***	0.0441
<i>rdperint</i>	-0.2268	0.432	-0.0813	0.1077	0.672	0.0361
<i>IntoverD</i>	-0.0188	0.692	-0.0067	0.0417	0.318	0.0140
<i>HHI</i>	0.3825	0.379	0.1372	0.4907	0.249	0.1644
<i>phd_ma</i>	-0.0167	0.128	-0.0060	0.0114	0.334	0.0038
<i>ipicsec</i>	0.0007	0.691	0.0002	0.0004	0.794	0.0001

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE2: Wald $\chi^2(6)=36.05$ Prob > $\chi^2=0.0000$

For PCRE2: Wald $\chi^2(6)=32.46$ Prob > $\chi^2=0.0000$

Regression results of PDRE3 and PCRE3 models include coefficient, p-value, and average marginal effect, which are shown in Table 178. These models analyze the effect of *external R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE3 model focuses on the relationship between product innovation and *external R&D expenditure*, which is shown in Table 178. Because the Wald test and all individual z-statistics (not shown here) are not statistically significant, the PDRE3 model is not shown here. Hence, the null hypothesis, $H1b_0$, could not be tested for medium-low technology manufacturing industries.

The PCRE3 model focuses on the relationship between process innovation and *external R&D expenditure*, which is shown in Table 178. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity*, *turnover*, and the *number of highly educated R&D personnel*. Hence, the null hypothesis, $H3b_0$, is rejected.

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.26 in the likelihood of occurrence of process innovation.
- A 1 percent increase in the value of *total R&D expenditure*, on average, leads to an increase of 3.63 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.99 percent in the likelihood of occurrence of process innovation.

Table 178: Regression Results of PDRE3 and PCRE3 Models – MLT

Variable Name	PDRE3			PCRE3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpD</i>				0.0056	0.583	0.0019
<i>rdperint</i>				0.7765	0.067 *	0.2644
<i>IntoverD</i>				0.1066	0.007 ***	0.0363
<i>HHI</i>				0.3903	0.356	0.1329
<i>phd_ma</i>				0.0292	0.025 **	0.0099
<i>ipicsec</i>				0.0008	0.570	0.0003

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE3: Wald $\chi^2(6)=5.30$ Prob > $\chi^2=0.5056$

For PCRE3: Wald $\chi^2(6)=24.52$ Prob > $\chi^2=0.0004$

Regression results of PDRE4 and PCRE4 models include coefficient, p-value, and average marginal effect, which are shown in Table 179. These models analyze the effect of *external-domestic R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE4 model focuses on the relationship between product innovation and *external-domestic R&D expenditure*, which is shown in Table 179. Because the Wald test and all individual z-statistics (not shown here) are not statistically significant, the PDRE4 model is not shown here. Hence, the null hypothesis, $H1_{C0}$, could not be tested for medium-low technology manufacturing industries.

The PCRE4 model focuses on the relationship between process innovation and *external-domestic R&D expenditure*, which is shown in Table 179. In this model, independent variables are not statistically significant at 10% level, except *R&D*

personnel intensity, *turnover*, and the *number of highly educated R&D personnel*. Hence, the null hypothesis, $H3c_0$, is rejected.

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.26 in the likelihood of occurrence of process innovation.
- A 1 percent increase in the value of *total R&D expenditure*, on average, leads to an increase of 3.64 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 1 percent in the likelihood of occurrence of process innovation.

Table 179: Regression Results of PDRE4 and PCRE4 Models – MLT

Variable Name	PDRE4			PCRE4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpdomD</i>				0.0045	0.644	0.0015
<i>rdperint</i>				0.7814	0.066 *	0.2661
<i>IntoverD</i>				0.1069	0.006 ***	0.0364
<i>HHI</i>				0.3898	0.357	0.1327
<i>phd_ma</i>				0.0295	0.022 **	0.0100
<i>ipicsec</i>				0.0008	0.586	0.0003

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE4: Wald $\chi^2(6)=4.98$ Prob > $\chi^2=0.5459$

For PCRE4: Wald $\chi^2(6)=23.69$ Prob > $\chi^2=0.0006$

Regression results of PDRE5 and PCRE5 models include coefficient, p-value, and average marginal effect, which are shown in Table 180. These models analyze the effect of *external-foreign R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE5 model focuses on the relationship between product innovation and *external-foreign R&D expenditure*, which is shown in Table 180. Because the Wald test and 5 of 6 individual z-statistics (not shown here) are not statistically significant, the PDRE5 model is not shown here. Hence, the null hypothesis, $H1d_0$, could not be tested for medium-low technology manufacturing industries.

The PCRE5 model focuses on the relationship between process innovation and *external-foreign R&D expenditure*, which is shown in Table 180. In this model,

independent variables are not statistically significant at 10% level, except *R&D personnel intensity*, *turnover*, and the *number of highly educated R&D personnel*. Hence, the null hypothesis, $H3d_0$, is rejected.

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.28 in the likelihood of occurrence of process innovation.
- A 1 percent increase in the value of *total R&D expenditure*, on average, leads to an increase of 3.62 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.92 percent in the likelihood of occurrence of process innovation.

Table 180: Regression Results of PDRE5 and PCRE5 Models – MLT

Variable Name	PDRE5			PCRE5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpforD</i>				0.0248	0.425	0.0084
<i>rdperint</i>				0.8083	0.056 *	0.2751
<i>IntoverD</i>				0.1063	0.007 ***	0.0362
<i>HHI</i>				0.3795	0.367	0.1292
<i>phd_ma</i>				0.0272	0.052 **	0.0092
<i>ipicsec</i>				0.0009	0.542	0.0003

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE5: Wald $\chi^2(6)=7.13$ Prob > $\chi^2=0.3093$

For PCRE5: Wald $\chi^2(6)=23.56$ Prob > $\chi^2=0.0006$

Regression results of PDRI1 and PCRI1 models include coefficient, p-value, and average marginal effect, which are shown in Table 181. These models analyze the effect *total R&D intensity* on the probability of product and process innovations, respectively.

The PDRI1 model focuses on the relationship between product innovation and *total R&D intensity*, which is shown in Table 181. In this model, independent variables are not statistically significant at the 10% level, except *total R&D intensity* and *turnover*. *Total R&D intensity* is statistically significant at 1% level. Hence, the null hypothesis, $H2_0$, is rejected. *Turnover* is statistically significant at the 10% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *total R&D intensity*, on average, leads to an increase of 1.06 in the likelihood of occurrence of product innovation.
- A 1 percent increase in the value of *turnover*, on average, leads to an increase of 3.29 percent in the likelihood of occurrence of product innovation.

The PCRI1 model focuses on the relationship between process innovation and *total R&D intensity*, which is shown in Table 181. In this model, independent variables are not statistically significant at the 10% level, except *turnover* and the *number of highly educated R&D personnel*. Hence, the null hypothesis, H_{40} , is not rejected. The *turnover* and the *number of highly educated R&D personnel* are statistically significant at 1% and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 3.89 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 1.04 percent in the likelihood of occurrence of process innovation.

Table 181: Regression Results of PDRI1 and PCRI1 Models – MLT

Variable Name	PDRI1			PCRI1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>totrdint</i>	2.9001	0.007 ***	1.0638	0.9063	0.295	0.3069
<i>rdperint</i>	-0.5937	0.514	-0.2178	0.4446	0.604	0.1506
<i>IntoverD</i>	0.0897	0.062 *	0.0329	0.1148	0.005 ***	0.0389
<i>HHI</i>	0.2879	0.535	0.1056	0.4234	0.320	0.1434
<i>phd_ma</i>	-0.0042	0.765	-0.0015	0.0307	0.020 **	0.0104
<i>ipicsec</i>	0.0011	0.479	0.0004	0.0007	0.603	0.0003

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI1: Wald $\chi^2(6) = 11.19$ Prob > $\chi^2 = 0.0826$

For PCRI1: Wald $\chi^2(6) = 23.43$ Prob > $\chi^2 = 0.0007$

Regression results of PDRI2 and PCRI2 models include coefficient, p-value, and average marginal effect, which are shown in Table 182. These models analyze the effect of *internal R&D intensity* on the probability of product and process innovations, respectively.

The PDRI2 model focuses on the relationship between product innovation and *internal R&D intensity*, which is shown in Table 182. In this model, independent variables are not statistically significant at the 10% level, except *internal R&D intensity* and *turnover*. *Internal R&D intensity* is statistically significant at 1% level. Hence, the null hypothesis, $H2a_0$, is rejected. *Turnover* is statistically significant at the 10% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *internal R&D intensity*, on average, leads to an increase of 0.99 in the likelihood of occurrence of product innovation.
- A 1 percent increase in the value of *turnover*, on average, leads to an increase of 3.26 percent in the likelihood of occurrence of product innovation.

Table 182: Regression Results of PDRI2 and PCRI2 Models – MLT

Variable Name	PDRI2			PCRI2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>intrdint</i>	2.6929	0.008 ***	0.9885	0.8613	0.310	0.2917
<i>rdperint</i>	-0.5287	0.557	-0.1941	0.4624	0.591	0.1566
<i>lntoverD</i>	0.0888	0.065 *	0.0326	0.1145	0.005 ***	0.0388
<i>HHI</i>	0.2832	0.541	0.1039	0.4219	0.321	0.1429
<i>phd_ma</i>	-0.0042	0.768	-0.0015	0.0308	0.020 **	0.0104
<i>ipicsec</i>	0.0012	0.473	0.0004	0.0008	0.600	0.0003

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI2: Wald $\chi^2(6)=10.90$ Prob > $\chi^2=0.0916$

For PCRI2: Wald $\chi^2(6)=23.33$ Prob > $\chi^2=0.0007$

The PCRI2 model focuses on the relationship between process innovation and *internal R&D intensity*, which is shown in Table 182. In this model, independent variables are not statistically significant at the 10% level, except *turnover* and the *number of highly educated R&D personnel*. Hence, the null hypothesis, $H4a_0$, is not rejected. The *turnover* and the *number of highly educated R&D personnel* are statistically significant at 1% and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 3.88 percent in the likelihood of occurrence of process innovation.

- 1 percent increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 1.04 percent in the likelihood of occurrence of process innovation.

Regression results of PDRI3 and PCRI3 models include coefficient, p-value, and average marginal effect, which are shown in Table 183. These models analyze the effect of *external R&D intensity* on the probability of product and process innovations, respectively.

The PDRI3 model focuses on the relationship between product innovation and *external R&D intensity*, which is shown in Table 183. In this model, independent variables are not statistically significant at the 10% level, except *external R&D intensity*, *R&D personnel intensity*, and *turnover*. *External R&D intensity* is statistically significant at 1% level. Hence, the null hypothesis, $H2b_0$, is rejected. *R&D personnel intensity* and *turnover* are statistically significant at the 10% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external R&D intensity*, on average, leads to an increase of 6.14 in the likelihood of occurrence of product innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.16 in the likelihood of occurrence of product innovation.
- A 1 percent increase in the value of *turnover*, on average, leads to an increase of 2.86 percent in the likelihood of occurrence of product innovation.

Table 183: Regression Results of PDRI3 and PCRI3 Models – MLT

Variable Name	PDRI3			PCRI3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extrdint</i>	16.638	0.004 ***	6.1406	1.5321	0.006 ***	0.5214
<i>rdperint</i>	0.4190	0.093 *	0.1546	0.6575	0.101	0.2238
<i>IntoverD</i>	0.0775	0.084 *	0.0286	0.1068	0.006 ***	0.0364
<i>HHI</i>	0.2168	0.633	0.0800	0.3978	0.347	0.1354
<i>phd_ma</i>	-0.0040	0.772	-0.0015	0.0305	0.016 **	0.0104
<i>ipicsec</i>	0.0012	0.464	0.0004	0.0008	0.590	0.0003

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI3: Wald $\chi^2(6) = 14.60$ Prob > $\chi^2 = 0.0236$

For PCRI3: Wald $\chi^2(6) = 29.64$ Prob > $\chi^2 = 0.0000$

The PCRI3 model focuses on the relationship between process innovation and *external R&D intensity*, which is shown in Table 183. In this model, independent variables are not statistically significant at the 10% level, except *external R&D intensity*, *turnover*, and the *number of highly educated R&D personnel*. *External R&D intensity* is statistically significant at the 1% level. Hence, the null hypothesis, $H4b_0$, is rejected. The *turnover* and the *number of highly educated R&D personnel* are statistically significant at 1% and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external R&D intensity*, on average, leads to an increase of 0.52 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 3.64 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 1.04 percent in the likelihood of occurrence of process innovation.

Regression results of PDRI4 and PCRI4 models include coefficient, p-value, and average marginal effect, which are shown in Table 184. These models analyze the effect of *external-domestic R&D intensity* on the probability of product and process innovations, respectively.

Table 184: Regression Results of PDRI4 and PCRI4 Models – MLT

Variable Name	PDRI4			PCRI4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extdomrdint</i>	1.0752	0.001 ***	0.3991	1.3569	0.008 ***	0.4618
<i>rdperint</i>	0.3318	0.141	0.1232	0.6631	0.100	0.2257
<i>IntoverD</i>	0.0727	0.103	0.0270	0.1068	0.006 ***	0.0363
<i>HHI</i>	0.2251	0.618	0.0836	0.3974	0.348	0.1353
<i>phd_ma</i>	-0.0040	0.763	-0.0015	0.0305	0.016 **	0.0104
<i>ipicsec</i>	0.0012	0.456	0.0004	0.0008	0.592	0.0003

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI4: Wald $\chi^2(6) = 25.64$ Prob > $\chi^2 = 0.0003$

For PCRI4: Wald $\chi^2(6) = 29.35$ Prob > $\chi^2 = 0.0001$

The PDRI4 model focuses on the relationship between product innovation and *external-domestic R&D intensity*, which is shown in Table 184. In this model,

independent variables are not statistically significant at the 10% level, except *external R&D intensity*. *External-domestic R&D intensity* is statistically significant at 1% level. Hence, the null hypothesis, $H2c_0$, is rejected. It means, *ceteris paribus*, that a unit increase in the value of *external-domestic R&D intensity*, on average, leads to an increase of 0.4 in the likelihood of occurrence of product innovation.

The PCRI4 model focuses on the relationship between process innovation and *external-domestic R&D intensity*, which is shown in Table 184. In this model, independent variables are not statistically significant at the 10% level, except *external-domestic R&D intensity*, *turnover*, and the *number of highly educated R&D personnel*. *External-domestic R&D intensity* is statistically significant at the 1% level. Hence, the null hypothesis, $H4c_0$, is rejected. The *turnover* and the *number of highly educated R&D personnel* are statistically significant at 1% and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external-domestic R&D intensity*, on average, leads to an increase of 0.46 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 3.63 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 1.04 percent in the likelihood of occurrence of process innovation.

Regression results of PDRI5 and PCRI5 models include coefficient, p-value, and average marginal effect, which are shown in Table 185. These models analyze the effect of *external-foreign R&D intensity* on the probability of product and process innovations, respectively.

The PDRI5 model focuses on the relationship between product innovation and *external-foreign R&D intensity*, which is shown in Table 185. Because the Wald test and 5 of 6 individual z-statistics (not shown here) are not statistically significant, the

PDRI5 model is not shown here. Hence, the null hypothesis, $H2d_0$, could not be tested for medium-low technology manufacturing industries.

Table 185: Regression Results of PDRI5 and PCRI5 Models – MLT

Variable Name	PDRI5			PCRI5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extfrgrdint</i>				73.626	0.603	25.076
<i>rdperint</i>				0.8173	0.056 *	0.2784
<i>IntoverD</i>				0.1084	0.006 ***	0.0369
<i>HHI</i>				0.3934	0.351	0.1340
<i>phd_ma</i>				0.0280	0.032 **	0.0096
<i>ipicsec</i>				0.0008	0.578	0.0003

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI5: Wald $\chi^2(6)=6.78$ Prob > $\chi^2=0.3417$

For PCRI5: Wald $\chi^2(6)=23.43$ Prob > $\chi^2=0.0007$

The PCRI5 model focuses on the relationship between process innovation and *external-foreign R&D intensity*, which is shown in Table 185. In this model, independent variables are not statistically significant at the 10% level, except *R&D personnel intensity*, *turnover*, and the *number of highly educated R&D personnel*. Hence, the null hypothesis, $H4d_0$, is not rejected. The *turnover* and the *number of highly educated R&D personnel* are statistically significant at 1% and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 3.69 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.96 percent in the likelihood of occurrence of process innovation.

According to the analysis of Turkish manufacturing industry with medium-low technology, there are many findings in terms of product innovation. These are:

- R&D expenditure variables such as total and internal are statistically significant and they have positive effect on the likelihood of occurrence of product innovation. It means that more total and *internal R&D expenditures* increase the likelihood of occurrence of product innovation.

- R&D intensity variables except external-foreign are statistically significant and they have positive effect on the likelihood of occurrence of product innovation. It means that more of these intensities increase the likelihood of occurrence of product innovation. The most effective intensity type is *external R&D intensity*.
- According to PDRE1 model, other independent variables are not statistically significant at 10% level. According to PDRI1 model, *turnover* is statistically significant and has positive effect on the likelihood of occurrence of product innovation. It means that more *turnover* increases the likelihood of occurrence of product innovation.

According to the analysis of Turkish manufacturing industry with medium-low technology, there are many findings in terms of process innovation. These are:

- R&D expenditure variables except total and internal are not statistically significant at 10% level. Total and *internal R&D expenditures* are statistically significant and have positive effect on the likelihood of occurrence of process innovation. It means that more total and *internal R&D expenditures* increase the likelihood of occurrence of process innovation. The most effective expenditure type is *total R&D expenditure*.
- R&D intensity variables except external and external-domestic are not statistically significant at 10% level. External and external-domestic R&D intensities have positive effect on the likelihood of occurrence of process innovation. It means that more of these intensities increase the likelihood of occurrence of process innovation. The most effective intensity type is *external R&D intensity*.
- According to PCRE1 model, other independent variables are not statistically significant at 10% level. According to PCRI1 model, *turnover* and the *number of highly educated R&D personnel* are statistically significant and have positive effects on the likelihood of occurrence of process innovation. It means that more *turnover* and more highly educated

R&D personnel increase the likelihood of occurrence of process innovation.

Results of the analyses are also viewed by comparing product and process innovation in terms of Turkish manufacturing industry with medium-low technology. These are:

- The impact of *total* and *internal R&D expenditures* on the likelihood of occurrence of product innovation are greater than their impacts on the likelihood of occurrence of process innovation.
- *Total* and *internal R&D intensity* affect only the likelihood of occurrence of product innovation positively.
- The impact of *external R&D intensity* on the likelihood of occurrence of product innovation is greater than its impact on the likelihood of occurrence of process innovation.
- The impact of *external-foreign R&D intensity* on the likelihood of occurrence of product innovation is like its impact on the likelihood of occurrence of process innovation.

5.1.4. Low Technology Manufacturing Industries (LT)

Firms that are engaged in R&D in the low technology manufacturing industry are analyzed with twenty models such as 10 product innovation models and 10 process innovation models, which are shown in Table 3 that is in Chapter 3 and in Appendix 7, 8, 9, and 10.

Regression results of PDRE1 and PCRE1 models include coefficient, p-value, and average marginal effect, which are shown in Table 186. These models analyze the effect of *total R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE1 model focuses on the relationship between product innovation and *total R&D expenditure*, which is shown in Table 186. In this model, independent variables are not statistically significant at 10% level, except *total R&D expenditure*,

turnover, and *HHI*. *Total R&D expenditure* is statistically significant at the 1% level. Hence, the null hypothesis, $H1_0$, is rejected. *Turnover* and *HHI* are statistically significant at 10% and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A 1 percent increase in the value of *total R&D expenditure*, on average, leads to an increase of 3.28 percent in the likelihood of occurrence of product innovation.
- A 1 percent increase in the value of *turnover*, on average, leads to an increase of 3.79 percent in the likelihood of occurrence of product innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 2.88 in the likelihood of occurrence of product innovation.

Table 186: Regression Results of PDRE1 and PCRE1 Models – LT

Variable Name	PDRE1			PCRE1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntrdexpD</i>	0.0964	0.015 ***	0.0328	0.0866	0.055 *	0.0258
<i>rdperint</i>	-0.0493	0.968	-0.0168	1.8113	0.035 **	0.5397
<i>IntoverD</i>	0.1113	0.067 *	0.0379	0.2459	0.000 ***	0.0733
<i>HHI</i>	8.4635	0.036 **	2.8804	7.1678	0.213	2.1357
<i>phd_ma</i>	0.0004	0.968	0.0002	-0.0152	0.280	-0.0045
<i>ipicsec</i>	-0.0010	0.647	-0.0004	0.0015	0.542	0.0005

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE1: Wald $\chi^2(6)=19.83$ Prob > $\chi^2=0.0030$

For PCRE1: Wald $\chi^2(6)=35.01$ Prob > $\chi^2=0.0000$

The PCRE1 model focuses on the relationship between process innovation and *total R&D expenditure*, which is shown in Table 186. In this model, independent variables are not statistically significant at 10% level, except *total R&D expenditure*, *R&D personnel intensity*, and *turnover*. *Total R&D expenditure* is statistically significant at the 10% level. Hence, the null hypothesis, $H3_0$, is rejected. *R&D personnel intensity* and *turnover* are statistically significant at 5% and 10% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *total R&D expenditure*, on average, leads to an increase of 2.58 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.54 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 7.33 percent in the likelihood of occurrence of process innovation.

Regression results of PDRE2 and PCRE2 models include coefficient, p-value, and average marginal effect, which are shown in Table 187. These models analyze the effect of *internal R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE2 model focuses on the relationship between product innovation and *internal R&D expenditure*, which is shown in Table 187. In this model, independent variables are not statistically significant at 10% level, except *internal R&D expenditure*, *turnover*, and *HHI*. *Internal R&D expenditure* is statistically significant at the 5% level. Hence, the null hypothesis, $H1a_0$, is rejected. *Turnover* and *HHI* are statistically significant at 10% and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A 1 percent increase in the value of *internal R&D expenditure*, on average, leads to an increase of 3.20 percent in the likelihood of occurrence of product innovation.
- A 1 percent increase in the value of *turnover*, on average, leads to an increase of 3.85 percent in the likelihood of occurrence of product innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 2.88 in the likelihood of occurrence of product innovation.

The PCRE2 model focuses on the relationship between process innovation and *internal R&D expenditure*, which is shown in Table 187. In this model, independent variables are not statistically significant at 10% level, except *internal R&D*

expenditure, *R&D personnel intensity*, and *turnover*. *Internal R&D expenditure* is statistically significant at the 5% level. Hence, the null hypothesis, $H3a_0$, is rejected. *R&D personnel intensity* and *turnover* are statistically significant at 5% and 1% levels, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *internal R&D expenditure*, on average, leads to an increase of 2.78 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.53 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 7.23 percent in the likelihood of occurrence of process innovation.

Table 187: Regression Results of PDRE2 and PCRE2 Models – LT

Variable Name	PDRE2			PCRE2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntintrdexpD</i>	0.0939	0.022 **	0.0320	0.0934	0.042 **	0.0278
<i>rdperint</i>	-0.0336	0.978	-0.0114	1.7625	0.041 **	0.5245
<i>IntoverD</i>	0.1129	0.064 *	0.0385	0.2431	0.000 ***	0.0723
<i>HHI</i>	8.4517	0.037 **	2.8779	7.1977	0.213	2.1420
<i>phd_ma</i>	0.0005	0.963	0.0002	-0.0158	0.261	-0.0047
<i>ipicsec</i>	-0.0010	0.652	-0.0003	0.0016	0.539	0.0005

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE2: Wald $\chi^2(6)=19.13$ Prob > $\chi^2=0.0040$

For PCRE2: Wald $\chi^2(6)=35.91$ Prob > $\chi^2=0.0000$

Regression results of PDRE3 and PCRE3 models include coefficient, p-value, and average marginal effect, which are shown in Table 188. These models analyze the effect of *external R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE3 model focuses on the relationship between product innovation and *external R&D expenditure*, which is shown in Table 188. In this model, independent variables are not statistically significant at the 10% level, except *external R&D expenditure*, *turnover*, and *HHI*. *External R&D expenditure* is statistically significant at the 5% level. Hence, the null hypothesis, $H1b_0$, is rejected. *Turnover* and *HHI* are

statistically significant at the 1% and 10% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A 1 percent increase in the value of *external R&D expenditure*, on average, leads to an increase of 0.8 percent in the likelihood of occurrence of product innovation.
- A 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.09 percent in the likelihood of occurrence of product innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 2.69 in the likelihood of occurrence of product innovation.

Table 188: Regression Results of PDRE3 and PCRE3 Models – LT

Variable Name	PDRE3			PCRE3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpD</i>	0.0232	0.012 **	0.0080	-0.0019	0.865	-0.0006
<i>rdperint</i>	0.4475	0.672	0.1536	2.5603	0.004 ***	0.7695
<i>IntoverD</i>	0.1482	0.008 ***	0.0509	0.2919	0.000 ***	0.0877
<i>HHI</i>	7.8388	0.055 *	2.6912	6.9559	0.221	2.0906
<i>phd_ma</i>	0.0072	0.493	0.0025	-0.0088	0.535	-0.0026
<i>ipicsec</i>	-0.0009	0.692	-0.0003	0.0016	0.530	0.0005

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE3: Wald chi2(6)=21.67 Prob > chi2=0.0014

For PCRE3: Wald chi2(6)=30.57 Prob > chi2=0.0000

The PCRE3 model focuses on the relationship between process innovation and *external R&D expenditure*, which is shown in Table 188. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity* and *turnover*. Hence, the null hypothesis, *H3b₀*, is not rejected. *R&D personnel intensity* and *turnover* are statistically significant at the 1% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.77 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 8.77 percent in the likelihood of occurrence of process innovation.

Regression results of PDRE4 and PCRE4 models include coefficient, p-value, and average marginal effect, which are shown in Table 189. These models analyze the effect of *external-domestic R&D expenditure* on the probability of product and process innovations, respectively.

Table 189: Regression Results of PDRE4 and PCRE4 Models – LT

Variable Name	PDRE4			PCRE4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpdomD</i>	0.0149	0.122	0.0051	-0.0087	0.465	-0.0026
<i>rdperint</i>	0.5531	0.607	0.1905	2.5754	0.004 ***	0.7736
<i>IntoverD</i>	0.1527	0.006 ***	0.0526	0.2938	0.000 ***	0.0883
<i>HHI</i>	7.8101	0.057 *	2.6902	6.9457	0.222	2.0862
<i>phd_ma</i>	0.0072	0.508	0.0025	-0.0087	0.544	-0.0026
<i>ipicsec</i>	-0.0009	0.696	-0.0003	0.0016	0.524	0.0005

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE4: Wald chi2(6)=17.35 Prob > chi2=0.0081

For PCRE4: Wald chi2(6)=30.91 Prob > chi2=0.0000

The PDRE4 model focuses on the relationship between product innovation and *external-domestic R&D expenditure*, which is shown in Table 189. In this model, independent variables are not statistically significant at the 10% level, except *turnover* and *HHI*. Hence, the null hypothesis, $H1c_0$, is not rejected. *Turnover* and *HHI* are statistically significant at the 1% and 10% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.26 percent in the likelihood of occurrence of product innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 2.69 in the likelihood of occurrence of product innovation.

The PCRE4 model focuses on the relationship between process innovation and *external-domestic R&D expenditure*, which is shown in Table 189. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity* and *turnover*. Hence, the null hypothesis, $H3c_0$, is not rejected. *R&D personnel intensity* and *turnover* are statistically significant at the 1% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.77 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 8.83 percent in the likelihood of occurrence of process innovation.

Regression results of PDRE5 and PCRE5 models include coefficient, p-value, and average marginal effect, which are shown in Table 190. These models analyze the effect of *external-foreign R&D expenditure* on the probability of product and process innovations, respectively.

Table 190: Regression Results of PDRE5 and PCRE5 Models – LT

Variable Name	PDRE5			PCRE5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpforD</i>	0.0396	0.003 ***	0.0136	0.0419	0.008 ***	0.0125
<i>rdperint</i>	0.3702	0.725	0.1271	2.4617	0.007 ***	0.7364
<i>IntoverD</i>	0.1483	0.007 ***	0.0509	0.2862	0.000 ***	0.0856
<i>HHI</i>	7.6685	0.061 *	2.6325	6.7079	0.234	2.0067
<i>phd_ma</i>	0.0058	0.572	0.0020	-0.0114	0.388	-0.0034
<i>ipicsec</i>	-0.0007	0.749	-0.0002	0.0017	0.512	0.0005

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE5: Wald chi2(6)=24.36 Prob > chi2=0.0004

For PCRE5: Wald chi2(6)=42.56 Prob > chi2=0.0000

The PDRE5 model focuses on the relationship between product innovation and *external-foreign R&D expenditure*, which is shown in Table 190. In this model, independent variables are not statistically significant at the 10% level, except *external-foreign R&D expenditure*, *turnover*, and *HHI*. *External-foreign R&D expenditure* is statistically significant at the 10% level. Hence, the null hypothesis, $H1d_0$, is rejected. *Turnover* and *HHI* are statistically significant at the 1% and 10% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A 1 percent increase in the value of *external-foreign R&D expenditure*, on average, leads to an increase of 1.36 percent in the likelihood of occurrence of product innovation.
- A 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.09 percent in the likelihood of occurrence of product innovation.

- An increase in *HHI* of 0.01, on average, leads to an increase of 2.63 in the likelihood of occurrence of product innovation.

The PCRE5 model focuses on the relationship between process innovation and *external-foreign R&D expenditure*, which is shown in Table 190. In this model, independent variables such as *external-foreign R&D expenditure*, *R&D personnel intensity*, and *turnover* are statistically significant at the 1% level. Hence, the null hypothesis, $H3d_0$, is rejected. The rest of independent variables are not statistically significant at the 10% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *external-foreign R&D expenditure*, on average, leads to an increase of 1.25 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.74 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 8.56 percent in the likelihood of occurrence of process innovation.

Regression results of PDRI1 and PCRI1 models include coefficient, p-value, and average marginal effect, which are shown in Table 191. These models analyze the effect *total R&D intensity* on the probability of product and process innovations, respectively.

The PDRI1 model focuses on the relationship between product innovation and *total R&D intensity*, which is shown in Table 191. In this model, independent variables are not statistically significant at the 10% level, except *total R&D intensity*, *turnover*, and *HHI*. *Total R&D intensity* is statistically significant at 5% level. Hence, the null hypothesis, $H2_0$, is rejected. *Turnover* and *HHI* are statistically significant at the 1% and 10% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *total R&D intensity*, on average, leads to an increase of 1.06 in the likelihood of occurrence of product innovation.

- A 1 percent increase in the value of *turnover*, on average, leads to an increase of 3.29 percent in the likelihood of occurrence of product innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 2.69 in the likelihood of occurrence of product innovation.

The PCRI1 model focuses on the relationship between process innovation and *total R&D intensity*, which is shown in Table 191. In this model, independent variables are not statistically significant at the 10% level, except *R&D personnel intensity* and *turnover*. Hence, the null hypothesis, H_{40} , is not rejected. *R&D personnel intensity* and *turnover* are statistically significant at the 10% and 1% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.64 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 8.99 percent in the likelihood of occurrence of process innovation.

Table 191: Regression Results of PDRI1 and PCRI1 Models – LT

Variable Name	PDRI1			PCRI1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>totrdint</i>	2.4602	0.019 **	0.8433	1.5334	0.155	0.4592
<i>rdperint</i>	-0.6039	0.559	-0.2070	2.1336	0.061 *	0.6390
<i>lntoverD</i>	0.1645	0.003 ***	0.0564	0.3002	0.000 ***	0.0899
<i>HHI</i>	7.8584	0.063 *	2.6939	6.9803	0.222	2.0906
<i>phd_ma</i>	0.0079	0.478	0.0027	-0.0096	0.494	-0.0029
<i>ipicsec</i>	-0.0009	0.693	-0.0003	0.0017	0.514	0.0005

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI1: Wald $\chi^2(6)=21.15$ Prob > $\chi^2=0.0017$

For PCRI1: Wald $\chi^2(6)=81.88$ Prob > $\chi^2=0.0000$

Regression results of PDRI2 and PCRI2 models include coefficient, p-value, and average marginal effect, which are shown in Table 192. These models analyze the effect *internal R&D intensity* on the probability of product and process innovations, respectively.

The PDRI2 model focuses on the relationship between product innovation and *internal R&D intensity*, which is shown in Table 192. In this model, independent variables are not statistically significant at the 10% level, except *internal R&D intensity*, *turnover*, and *HHI*. *Internal R&D intensity* is statistically significant at 10% level. Hence, the null hypothesis, $H2a_0$, is rejected. *Turnover* and *HHI* are statistically significant at the 1% and 10% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *internal R&D intensity*, on average, leads to an increase of 0.92 in the likelihood of occurrence of product innovation.
- A 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.65 percent in the likelihood of occurrence of product innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 2.69 in the likelihood of occurrence of product innovation.

Table 192: Regression Results of PDRI2 and PCRI2 Models – LT

Variable Name	PDRI2			PCRI2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>Intrdint</i>	2.6901	0.051 *	0.9221	1.3237	0.249	0.3968
<i>Rdperint</i>	-0.6568	0.521	-0.2252	2.1962	0.058 *	0.6583
<i>IntoverD</i>	0.1648	0.003 ***	0.0565	0.2985	0.000 ***	0.0895
<i>HHI</i>	7.8955	0.063 *	2.7065	7.0104	0.221	2.1013
<i>phd_ma</i>	0.0079	0.477	0.0027	-0.0094	0.503	-0.0028
<i>Ipicsc</i>	-0.0009	0.695	-0.0003	0.0016	0.519	0.0005

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI2: Wald $\chi^2(6)=19.82$ Prob > $\chi^2=0.0030$

For PCRI2: Wald $\chi^2(6)=31.48$ Prob > $\chi^2=0.0000$

The PCRI2 model focuses on the relationship between process innovation and *internal R&D intensity*, which is shown in Table 192. In this model, independent variables are not statistically significant at the 10% level, except *R&D personnel intensity* and *turnover*. Hence, the null hypothesis, $H4a_0$, is not rejected. *R&D personnel intensity* and *turnover* are statistically significant at the 10% and 1% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.66 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 8.95 percent in the likelihood of occurrence of process innovation.

Regression results of PDRI3 and PCRI3 models include coefficient, p-value, and average marginal effect, which are shown in Table 193. These models analyze the effect *external R&D intensity* on the probability of product and process innovations, respectively.

Table 193: Regression Results of PDRI3 and PCRI3 Models – LT

Variable Name	PDRI3			PCRI3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extrdint</i>	1.0386	0.415	0.3582	6.5320	0.003 ***	1.9599
<i>rdperint</i>	0.5459	0.612	0.1883	2.4472	0.004 ***	0.7343
<i>IntoverD</i>	0.1564	0.005 ***	0.0539	0.2924	0.000 ***	0.0877
<i>HHI</i>	7.8002	0.059 *	2.6900	6.8377	0.223	2.0516
<i>phd_ma</i>	0.0073	0.511	0.0025	-0.0091	0.518	-0.0027
<i>ipicsec</i>	-0.0008	0.710	-0.0003	0.0016	0.523	0.0005

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI3: Wald chi2(6)=14.22 Prob > chi2=0.0273

For PCRI3: Wald chi2(6)=36.99 Prob > chi2=0.0000

The PDRI3 model focuses on the relationship between product innovation and *external R&D intensity*, which is shown in Table 193. In this model, independent variables are not statistically significant at the 10% level, except *turnover* and *HHI*. Hence, the null hypothesis, $H2b_0$, is not rejected. *Turnover* and *HHI* are statistically significant at the 1% and 10% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.39 percent in the likelihood of occurrence of product innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 2.69 in the likelihood of occurrence of product innovation.

The PCRI3 model focuses on the relationship between process innovation and *external R&D intensity*, which is shown in Table 193. In this model, independent variables such as *external R&D intensity*, *R&D personnel intensity*, and *turnover* are statistically significant at the 1% level. Hence, the null hypothesis, $H4b_0$, is rejected. The rest of the independent variables are not statistically significant at the 10% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external R&D intensity*, on average, leads to an increase of 1.96 in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.73 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 8.77 percent in the likelihood of occurrence of process innovation.

Regression results of PDRI4 and PCRI4 models include coefficient, p-value, and average marginal effect, which are shown in Table 194. These models analyze the effect *external-domestic R&D intensity* on the probability of product and process innovations, respectively.

Table 194: Regression Results of PDRI4 and PCRI4 Models – LT

Variable Name	PDRI4			PCRI4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extdomrdint</i>	-2.3293	0.467	-0.8034	7.3522	0.005 ***	2.2088
<i>rdperint</i>	0.5698	0.596	0.1965	2.4669	0.004 ***	0.7411
<i>IntoverD</i>	0.1555	0.005 ***	0.0536	0.2920	0.000 ***	0.0877
<i>HHI</i>	7.8521	0.059 *	2.7083	6.9066	0.221	2.0750
<i>phd_ma</i>	0.0074	0.505	0.0026	-0.0089	0.526	-0.0027
<i>ipicsec</i>	-0.0009	0.705	-0.0003	0.0016	0.522	0.0005

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI4: Wald $\chi^2(6) = 14.07$ Prob > $\chi^2 = 0.0289$

For PCRI4: Wald $\chi^2(6) = 35.21$ Prob > $\chi^2 = 0.0000$

The PDRI4 model focuses on the relationship between product innovation and *external-domestic R&D intensity*, which is shown in Table 194. In this model, independent variables are not statistically significant at the 10% level, except *turnover* and *HHI*. Hence, the null hypothesis, $H2c_0$, is not rejected. *Turnover* and *HHI* are

statistically significant at the 1% and 10% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.36 percent in the likelihood of occurrence of product innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 2.7 in the likelihood of occurrence of product innovation.

The PCRI4 model focuses on the relationship between process innovation and *external-domestic R&D intensity*, which is shown in Table 194. In this model, independent variables such as *external-domestic R&D intensity*, *R&D personnel intensity*, and *turnover* are statistically significant at the 1% level. Hence, the null hypothesis, $H4c_0$, is rejected. The rest of the independent variables are not statistically significant at the 10% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external-domestic R&D intensity*, on average, leads to an increase of 2.21 in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.74 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 8.77 percent in the likelihood of occurrence of process innovation.

Regression results of PDRI5 and PCRI5 models include coefficient, p-value, and average marginal effect, which are shown in Table 195. These models analyze the effect *external-foreign R&D intensity* on the probability of product and process innovations, respectively.

The PDRI5 model focuses on the relationship between product innovation and *external-foreign R&D intensity*, which is shown in Table 195. In this model, independent variables are not statistically significant at the 10% level, except *external-foreign R&D intensity*, *turnover*, and *HHI*. *External-foreign R&D intensity* is

statistically significant at the 1% level. Hence, the null hypothesis, $H2d_0$, is rejected. *Turnover* and *HHI* are statistically significant at the 1% and 10% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external-foreign R&D intensity*, on average, leads to an increase of 2.21 in the likelihood of occurrence of product innovation.
- A 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.95 percent in the likelihood of occurrence of product innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 2.7 in the likelihood of occurrence of product innovation.

Table 195: Regression Results of PDRI5 and PCRI5 Models – LT

Variable Name	PDRI5			PCRI5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extfrgrdint</i>	711.9	0.000 ***	243.50	458.74	0.183	137.44
<i>rdperint</i>	-0.019	0.987	-0.0064	2.4808	0.009 ***	0.7433
<i>IntoverD</i>	0.145	0.009 ***	0.0495	0.2905	0.000 ***	0.0870
<i>HHI</i>	7.895	0.056 *	2.7003	6.8116	0.223	2.0408
<i>phd_ma</i>	0.007	0.496	0.0025	-0.0111	0.409	-0.0033
<i>ipicsec</i>	-0.001	0.771	-0.0002	0.0017	0.511	0.0005

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI5: Wald $\chi^2(6) = 35.66$ Prob > $\chi^2 = 0.0000$

For PCRI5: Wald $\chi^2(6) = 31.86$ Prob > $\chi^2 = 0.0000$

The PCRI5 model focuses on the relationship between process innovation and *external-foreign R&D intensity*, which is shown in Table 195. In this model, independent variables such as *R&D personnel intensity* and *turnover* are statistically significant at the 1% level. The rest of the independent variables are not statistically significant at the 10% level. Hence, the null hypothesis, $H4d_0$, is not rejected. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.74 in the likelihood of occurrence of process innovation.

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 8.70 percent in the likelihood of occurrence of process innovation.

According to the analysis of Turkish manufacturing industry with low technology, there are many findings in terms of product innovation. These are:

- R&D expenditure variables except external-domestic are statistically significant and they have positive effect on the likelihood of occurrence of product innovation. It means that more of these expenditures increase the likelihood of occurrence of product innovation. The most effective expenditure type is *total R&D expenditure*.
- R&D intensity variables except external and external-domestic are statistically significant and they have positive effect on the likelihood of occurrence of product innovation. It means that more of these intensities increase the likelihood of occurrence of product innovation. The most effective intensity type is *external-foreign R&D intensity*.
- According to PDRE1 and PDRI1 models, *turnover* and *HHI* are statistically significant, and they have positive effect on the likelihood of occurrence of product innovation. It means that more *turnover* and more concentrated LT manufacturing industries increase the likelihood of occurrence of product innovation.

According to the analysis of Turkish manufacturing industry with low technology, there are many findings in terms of process innovation. These are:

- R&D expenditure variables except external and external-domestic are statistically significant and they have positive effect on the likelihood of occurrence of process innovation. It means that more of these expenditures increase the likelihood of occurrence of process innovation. The most effective expenditure type is *internal R&D expenditure*.
- R&D intensity variables except external and external-domestic are not statistically significant at 10% level. External and external-domestic R&D intensities have positive effect on the likelihood of occurrence of process

innovation. It means that more of these intensities increase the likelihood of occurrence of process innovation. The most effective intensity type is *external-domestic R&D intensity*.

- According to PCRE1 and PCRI1 models, *R&D personnel intensity* and *turnover* are statistically significant, and they have positive effects on the likelihood of occurrence of process innovation. It means that more *R&D personnel intensity* and more *turnover* increase the likelihood of occurrence of process innovation.

Results of the analyses are also viewed by comparing product and process innovation in terms of Turkish manufacturing industry with low education intensity. These are:

- *Total* and *internal R&D expenditure* affect only the likelihood of occurrence of process innovation positively.
- The impact of *external-foreign R&D expenditure* on the likelihood of occurrence of process innovation is greater than its impact on the likelihood of occurrence of product innovation.
- *Total, internal, and external-foreign R&D intensity* affect only the likelihood of occurrence of product innovation positively.

Results and findings from the analysis of Turkish manufacturing industry by technology intensity classification are presented here. The differences in terms of the effects of R&D expenditures and R&D intensities on the likelihood of occurrence of product and process innovations are investigated with the twenty models for each class. The results of the analyses in terms of product and process innovation are summarized in Appendix 13 and 14, which presented many statistics about R&D expenditure and R&D intensity variables such as their positive or negative effects, their significance level, and their average marginal effect. Results of the analyses are also viewed by comparing product and process innovation according to technology intensity classification.

The effects of the rest of independent variables such as *turnover*, *HHI*, the *number of highly educated R&D personnel*, and *industrial production index by manufacturing industry* are explained generally, especially by focusing on the PDRE1 and PDRI1 (product innovation models), and PCRE1 and PCRI1 (process innovation models). Because these models include two main and inclusive independent variables such as *total R&D expenditure* and *total R&D intensity*. To explain the results, the effects of R&D expenditure is interpreted in terms of percentages, and the effects of R&D intensity is interpreted in terms of units.

In the next, the analysis of Turkish manufacturing industry by education intensity classification is presented.

5.2. Turkish Manufacturing Industry Analysis – Education Intensity (EII)

The analysis of all Turkish manufacturing industry by education intensity classification include all manufacturing industries, except manufacture of tobacco products. This classification includes High Education Intensity (HEI), Medium-High Education Intensity (MHEI), Medium-Low Education Intensity (MLEI), and Low Education Intensity (LEI). This classification is prepared by using education level of R&D personnel data within the framework of this dissertation. It is explained in the research design part.

According to Radas and Božić (2009), the share of highly educated employees has a positive impact on product innovation. So, investigation of highly educated employees and their effects on product and process innovation is significant. There are two points to investigate in terms of education. On the one hand, firms that are engaged in R&D in Turkish manufacturing industry are analyzed by the education intensity classification to reveal the differences among industries by education intensity. On the other hand, the *number of highly educated R&D personnel* who works in firms that are engaged in R&D in Turkish manufacturing industry is used as an independent variable to see their effects on both innovations.

5.2.1. Manufacturing Industries with High Education Intensity (HEI)

Firms that are engaged in R&D in Turkish manufacturing industry with high education intensity are analyzed by with twenty models such as 10 product innovation models and 10 process innovation models, which are shown in Table 3 that is in Chapter 3 and in Appendix 7, 8, 9, and 10.

Regression results of PDRE1 and PCRE1 models include coefficient, p-value, and average marginal effect, which are shown in Table 196. These models analyze the effect of *total R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE1 model focuses on the relationship between product innovation and *total R&D expenditure*, which is shown in Table 196. In this model, independent variables are not statistically significant at 10% level, except *total R&D expenditure* and the *number of highly educated R&D personnel*. *Total R&D expenditure* and the *number of highly educated R&D personnel* are statistically significant at the 5% level. Hence, the null hypothesis, $H1_0$, is rejected. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *total R&D expenditure*, on average, leads to an increase of 3.55 percent in the likelihood of occurrence of product innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.007 in the likelihood of occurrence of product innovation.

The PCRE1 model focuses on the relationship between process innovation and *total R&D expenditure*, which is shown in Table 196. In this model, independent variables are not statistically significant at 10% level, except *industrial production index by manufacturing industry*. Hence, the null hypothesis, $H3_0$, is not rejected. *Industrial production index by manufacturing industry* is statistically significant at 5% level. It means, *ceteris paribus*, that 1 percent increase in the value of *industrial*

production index by manufacturing industry, on average, leads to an increase of 0.09 percent in the likelihood of occurrence of process innovation.

Table 196: Regression Results of PDRE1 and PCRE1 Models – HEI

Variable Name	PDRE1			PCRE1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntrdexpD</i>	0.1368	0.038 **	0.0355	0.0998	0.114	0.0250
<i>rdperint</i>	-0.6873	0.123	-0.1785	-0.0572	0.873	-0.0144
<i>IntoverD</i>	-0.0260	0.683	-0.0067	0.1026	0.151	0.0257
<i>HHI</i>	2.4269	0.126	0.6303	-0.0493	0.975	-0.0124
<i>phd_ma</i>	0.0277	0.018 **	0.0072	0.0011	0.544	0.0003
<i>ipicsec</i>	0.0007	0.682	0.0002	0.0036	0.046 **	0.0009

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE1: Wald chi2(6)=30.54 Prob > chi2=0.0000

For PCRE1: Wald chi2(6)=27.79 Prob > chi2=0.0001

Regression results of PDRE2 and PCRE2 models include coefficient, p-value, and average marginal effect, which are shown in Table 197. These models analyze the effect of *internal R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE2 model focuses on the relationship between product innovation and *internal R&D expenditure*, which is shown in Table 197. In this model, independent variables are not statistically significant at 10% level, except *internal R&D expenditure* and the *number of highly educated R&D personnel*. *Internal R&D expenditure* and the *number of highly educated R&D personnel* are statistically significant at the 5% level. Hence, the null hypothesis, $H1a_0$, is rejected. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *internal R&D expenditure*, on average, leads to an increase of 3.88 percent in the likelihood of occurrence of product innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.007 in the likelihood of occurrence of product innovation.

The PCRE2 model focuses on the relationship between process innovation and *internal R&D expenditure*, which is shown in Table 197. In this model, independent

variables are not statistically significant at 10% level, except *industrial production index by manufacturing industry*. Hence, the null hypothesis, $H3a_0$, is not rejected. *Industrial production index by manufacturing industry* is statistically significant at 5% level. It means, *ceteris paribus*, that 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.09 percent in the likelihood of occurrence of process innovation.

Table 197: Regression Results of PDRE2 and PCRE2 Models – HEI

Variable Name	PDRE2			PCRE2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntintrdexpD</i>	0.1497	0.021 **	0.0388	0.0979	0.129	0.0246
<i>rdperint</i>	-0.7138	0.107	-0.1850	-0.0460	0.898	-0.0115
<i>IntoverD</i>	-0.0329	0.602	-0.0085	0.1043	0.148	0.0262
<i>HHI</i>	2.4285	0.126	0.6294	-0.0339	0.983	-0.0085
<i>phd_ma</i>	0.0263	0.020 **	0.0068	0.0011	0.543	0.0003
<i>ipicsec</i>	0.0007	0.695	0.0388	0.0036	0.047 **	0.0009

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE2: Wald $\chi^2(6) = 31.44$ Prob > $\chi^2 = 0.0000$

For PCRE2: Wald $\chi^2(6) = 27.57$ Prob > $\chi^2 = 0.0001$

Regression results of PDRE3 and PCRE3 models include coefficient, p-value, and average marginal effect, which are shown in Table 198. These models analyze the effect of *external R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE3 model focuses on the relationship between product innovation and *external R&D expenditure*, which is shown in Table 198. In this model, independent variables are not statistically significant at 10% level, except the *number of highly educated R&D personnel*. Hence, the null hypothesis, $H1b_0$, is not rejected. The *number of highly educated R&D personnel* is statistically significant at the 1% level. It means, *ceteris paribus*, that a unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.011 in the likelihood of occurrence of product innovation.

The PCRE3 model focuses on the relationship between process innovation and *external R&D expenditure*, which is shown in Table 198. In this model, independent variables are not statistically significant at 10% level, except *turnover* and *industrial production index by manufacturing industry*. Hence, the null hypothesis, $H3b_0$, is not

rejected. *Turnover* and *industrial production index by manufacturing industry* are statistically significant at 1% and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.32 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.1 percent in the likelihood of occurrence of process innovation.

Table 198: Regression Results of PDRE3 and PCRE3 Models – HEI

Variable Name	PDRE3			PCRE3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpD</i>	0.0098	0.352	0.0026	0.0075	0.403	0.0019
<i>rdperint</i>	-0.3442	0.421	-0.0914	0.2735	0.408	0.0698
<i>IntoverD</i>	0.0507	0.326	0.0135	0.1691	0.000 ***	0.0432
<i>HHI</i>	2.5955	0.102	0.6889	0.1142	0.941	0.0291
<i>phd_ma</i>	0.0403	0.001 ***	0.0107	0.0026	0.473	0.0007
<i>ipicsec</i>	0.0010	0.556	0.0003	0.0038	0.028 **	0.0010

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE3: Wald chi2(6)=21.31 Prob > chi2=0.0001

For PCRE3: Wald chi2(6)=23.18 Prob > chi2=0.0007

Regression results of PDRE4 and PCRE4 models include coefficient, p-value, and average marginal effect, which are shown in Table 199. These models analyze the effect of *external-domestic R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE4 model focuses on the relationship between product innovation and *external-domestic R&D expenditure*, which is shown in Table 199. In this model, independent variables are not statistically significant at 10% level, except the *number of highly educated R&D personnel*. Hence, the null hypothesis, $H1_{C0}$, is not rejected. The *number of highly educated R&D personnel* is statistically significant at the 1% level. It means, *ceteris paribus*, that a unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.011 in the likelihood of occurrence of product innovation.

The PCRE4 model focuses on the relationship between process innovation and *external-domestic R&D expenditure*, which is shown in Table 199. In this model, independent variables are not statistically significant at 10% level, except *turnover* and *industrial production index by manufacturing industry*. Hence, the null hypothesis, $H3c_0$, is not rejected. The *turnover* and *industrial production index by manufacturing industry* are statistically significant at 1% and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.35 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.1 percent in the likelihood of occurrence of process innovation.

Table 199: Regression Results of PDRE4 and PCRE4 Models – HEI

Variable Name	PDRE4			PCRE4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpdomD</i>	0.0136	0.184	0.0036	0.0062	0.464	0.0016
<i>rdperint</i>	-0.3495	0.414	-0.0927	0.2757	0.404	0.0704
<i>IntoverD</i>	0.0516	0.321	0.0137	0.1704	0.000 ***	0.0435
<i>HHI</i>	2.6086	0.101	0.6920	0.1165	0.940	0.0297
<i>phd_ma</i>	0.0399	0.001 ***	0.0106	0.0027	0.477	0.0007
<i>ipicsec</i>	0.0010	0.567	0.0003	0.0038	0.030 **	0.0010

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE4: Wald $\chi^2(6) = 27.07$ Prob > $\chi^2 = 0.0001$

For PCRE4: Wald $\chi^2(6) = 22.72$ Prob > $\chi^2 = 0.0009$

Regression results of PDRE5 and PCRE5 models include coefficient, p-value, and average marginal effect, which are shown in Table 200. These models analyze the effect of *external-foreign R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE5 model focuses on the relationship between product innovation and *external-foreign R&D expenditure*, which is shown in Table 200. In this model, independent variables are not statistically significant at 10% level, except the *number of highly educated R&D personnel*. Hence, the null hypothesis, $H1d_0$, is not rejected. The *number of highly educated R&D personnel* is statistically significant at the 1%

level. It means, *ceteris paribus*, that a unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.011 in the likelihood of occurrence of product innovation.

Table 200: Regression Results of PDRE5 and PCRE5 Models – HEI

Variable Name	PDRE5			PCRE5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpforD</i>	0.0185	0.358	0.0049	0.0320	0.203	0.0081
<i>rdperint</i>	-0.3378	0.429	-0.0897	0.2487	0.456	0.0632
<i>IntoverD</i>	0.0491	0.337	0.0130	0.1632	0.001***	0.0415
<i>HHI</i>	2.5777	0.103	0.6841	0.1359	0.929	0.0345
<i>phd_ma</i>	0.0401	0.001 ***	0.0106	0.0027	0.490	0.0007
<i>ipicsec</i>	0.0011	0.535	0.0003	0.0040	0.022 **	0.0010

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE5: Wald chi2(6)=27.54 Prob > chi2=0.0001

For PCRE5: Wald chi2(6)=23.98 Prob > chi2=0.0005

The PCRE5 model focuses on the relationship between process innovation and *external-foreign R&D expenditure*, which is shown in Table 200. In this model, independent variables are not statistically significant at 10% level, except *turnover* and *industrial production index by manufacturing industry*. Hence, the null hypothesis, $H3d_0$, is not rejected. The *turnover* and *industrial production index by manufacturing industry* are statistically significant at 1% and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.15 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.1 percent in the likelihood of occurrence of process innovation.

Regression results of PDRI1 and PCRI1 models include coefficient, p-value, and average marginal effect, which are shown in Table 201. These models analyze the effect of *total R&D intensity* on the probability of product and process innovations, respectively.

The PDRI1 model focuses on the relationship between product innovation and *total R&D intensity*, which is shown in Table 201. In this model, independent variables

are not statistically significant at the 10% level, except the *number of highly educated R&D personnel*. Hence, the null hypothesis, H_{20} , is not rejected. The *number of highly educated R&D personnel* is statistically significant at the 1% level. It means, *ceteris paribus*, that a unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.01 in the likelihood of occurrence of product innovation.

Table 201: Regression Results of PDRI1 and PCRI1 Models – HEI

Variable Name	PDRI1			PCRI1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>totrdint</i>	1.5381	0.292	0.4071	0.9295	0.152	0.2367
<i>rdperint</i>	-0.6404	0.225	-0.1695	0.0778	0.831	0.0198
<i>IntoverD</i>	0.0640	0.224	0.0169	0.1786	0.000 ***	0.0455
<i>HHI</i>	2.5738	0.104	0.6812	0.0264	0.986	0.0067
<i>phd_ma</i>	0.0387	0.001 ***	0.0102	0.0022	0.512	0.0006
<i>ipicsec</i>	0.0010	0.575	0.0003	0.0038	0.030 **	0.0010

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI1: Wald $\chi^2(6)=23.15$ Prob > $\chi^2=0.0007$

For PCRI1: Wald $\chi^2(6)=22.90$ Prob > $\chi^2=0.0008$

The PCRI1 model focuses on the relationship between process innovation and *total R&D intensity*, which is shown in Table 201. In this model, independent variables are not statistically significant at 10% level, except *turnover* and *industrial production index by manufacturing industry*. Hence, the null hypothesis, H_{40} , is not rejected. The *turnover* and *industrial production index by manufacturing industry* are statistically significant at 1% and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.55 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.1 percent in the likelihood of occurrence of process innovation.

Regression results of PDRI2 and PCRI2 models include coefficient, p-value, and average marginal effect, which are shown in Table 202. These models analyze the

effect of *internal R&D intensity* on the probability of product and process innovations, respectively.

The PDRI2 model focuses on the relationship between product innovation and *internal R&D intensity*, which is shown in Table 202. In this model, independent variables are not statistically significant at the 10% level, except *HHI* and the *number of highly educated R&D personnel*. Hence, the null hypothesis, $H2a_0$, is not rejected. *HHI* and the *number of highly educated R&D personnel* are statistically significant at the 10% and 1% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- An increase in *HHI* of 0.01, on average, leads to an increase of 0.69 in the likelihood of occurrence of process innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.01 in the likelihood of occurrence of product innovation.

Table 202: Regression Results of PDRI2 and PCRI2 Models – HEI

Variable Name	PDRI2			PCRI2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>intrdint</i>	1.7925	0.246	0.4750	0.8453	0.378	0.2157
<i>rdperint</i>	-0.6723	0.204	-0.1782	0.1123	0.777	0.0287
<i>IntoverD</i>	0.0647	0.220	0.0172	0.1772	0.000 ***	0.0452
<i>HHI</i>	2.6051	0.099 *	0.6903	0.0793	0.959	0.0202
<i>phd_ma</i>	0.0383	0.001 ***	0.0102	0.0023	0.508	0.0006
<i>ipicsec</i>	0.0009	0.588	0.0002	0.0038	0.031 **	0.0010

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI2: Wald $\chi^2(6)=23.02$ Prob > $\chi^2=0.0008$

For PCRI2: Wald $\chi^2(6)=22.17$ Prob > $\chi^2=0.0011$

The PCRI2 model focuses on the relationship between process innovation and *internal R&D intensity*, which is shown in Table 202. In this model, independent variables are not statistically significant at 10% level, except *turnover* and *industrial production index by manufacturing industry*. Hence, the null hypothesis, $H4a_0$, is not rejected. The *turnover* and *industrial production index by manufacturing industry* are statistically significant at 1% and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.52 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.1 percent in the likelihood of occurrence of process innovation.

Regression results of PDRI3 and PCRI3 models include coefficient, p-value, and average marginal effect, which are shown in Table 203. These models analyze the effect of *external R&D intensity* on the probability of product and process innovations, respectively.

The PDRI3 model focuses on the relationship between product innovation and *external R&D intensity*, which is shown in Table 203. In this model, independent variables are not statistically significant at the 10% level, except the *number of highly educated R&D personnel*. Hence, the null hypothesis, $H2b_0$, is not rejected. The *number of highly educated R&D personnel* is statistically significant at the 1% level. It means, *ceteris paribus*, that a unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.011 in the likelihood of occurrence of product innovation.

Table 203: Regression Results of PDRI3 and PCRI3 Models – HEI

Variable Name	PDRI3			PCRI3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extrdint</i>	0.2984	0.255	0.0793	0.8804	0.000 ***	0.2246
<i>rdperint</i>	-0.3347	0.433	-0.0890	0.2767	0.397	0.0706
<i>lntoverD</i>	0.0534	0.299	0.0142	0.1733	0.000 ***	0.0442
<i>HHI</i>	2.5743	0.106	0.6845	0.0777	0.960	0.0198
<i>phd_ma</i>	0.0403	0.001 ***	0.0107	0.0027	0.476	0.0007
<i>ipicsec</i>	0.0010	0.567	0.0003	0.0038	0.029 **	0.0010

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI3: Wald chi2(6)=26.65 Prob > chi2=0.0002

For PCRI3: Wald chi2(6)=44.73 Prob > chi2=0.0000

The PCRI3 model focuses on the relationship between process innovation and *external R&D intensity*, which is shown in Table 203. In this model, independent variables are not statistically significant at 10% level, except *external R&D intensity*, *turnover*, and *industrial production index by manufacturing industry*. *External R&D*

intensity and *turnover* are statistically significant at the 1% level. Hence, the null hypothesis, $H4b_0$, is rejected. The *industrial production index by manufacturing industry* is statistically significant at 5% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external R&D intensity*, on average, leads to an increase of 0.23 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.42 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.1 percent in the likelihood of occurrence of process innovation.

Regression results of PDRI4 and PCRI4 models include coefficient, p-value, and average marginal effect, which are shown in Table 204. These models analyze the effect of *external-domestic R&D intensity* on the probability of product and process innovations, respectively.

Table 204: Regression Results of PDRI4 and PCRI4 Models – HEI

Variable Name	PDRI4			PCRI4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extdomrdint</i>	0.2924	0.246	0.0777	0.8717	0.000 ***	0.2224
<i>rdperint</i>	-0.3346	0.433	-0.0890	0.2772	0.397	0.0707
<i>IntoverD</i>	0.0534	0.299	0.0142	0.1733	0.000 ***	0.0442
<i>HHI</i>	2.5746	0.106	0.6846	0.0788	0.959	0.0201
<i>phd_ma</i>	0.0403	0.001 ***	0.0107	0.0027	0.475	0.0007
<i>ipicsec</i>	0.0010	0.567	0.0003	0.0038	0.030 **	0.0010

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI4: Wald $\chi^2(6) = 25.27$ Prob > $\chi^2 = 0.0003$

For PCRI4: Wald $\chi^2(6) = 46.64$ Prob > $\chi^2 = 0.0000$

The PDRI4 model focuses on the relationship between product innovation and *external-domestic R&D intensity*, which is shown in Table 204. In this model, independent variables are not statistically significant at the 10% level, except the *number of highly educated R&D personnel*. Hence, the null hypothesis, $H2c_0$, is not rejected. The *number of highly educated R&D personnel* is statistically significant at the 1% level. It means, *ceteris paribus*, that a unit increase in the value of the *number*

of highly educated R&D personnel, on average, leads to an increase of 0.011 in the likelihood of occurrence of product innovation.

The PCRI4 model focuses on the relationship between process innovation and *external-domestic R&D intensity*, which is shown in Table 204. In this model, independent variables are not statistically significant at 10% level, except *external-domestic R&D intensity*, *turnover*, and *industrial production index by manufacturing industry*. *External-domestic R&D intensity* and *turnover* are statistically significant at the 1% level. Hence, the null hypothesis, $H4c_0$, is rejected. The *industrial production index by manufacturing industry* is statistically significant at 5% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external R&D intensity*, on average, leads to an increase of 0.22 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.42 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.1 percent in the likelihood of occurrence of process innovation.

Regression results of PDRI5 and PCRI5 models include coefficient, p-value, and average marginal effect, which are shown in Table 205. These models analyze the effect of *external-foreign R&D intensity* on the probability of product and process innovations, respectively.

The PDRI5 model focuses on the relationship between product innovation and *external-foreign R&D intensity*, which is shown in Table 205. In this model, independent variables are not statistically significant at the 10% level, except the *number of highly educated R&D personnel*. Hence, the null hypothesis, $H2d_0$, is not rejected. The *number of highly educated R&D personnel* is statistically significant at the 1% level. It means, *ceteris paribus*, that a unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.011 in the likelihood of occurrence of product innovation.

The PCRI5 model focuses on the relationship between process innovation and *external-foreign R&D intensity*, which is shown in Table 205. In this model, independent variables are not statistically significant at 10% level, except *turnover* and *industrial production index by manufacturing industry*. Hence, the null hypothesis, $H4d_0$, is not rejected. *Turnover* and the *industrial production index by manufacturing industry* are statistically significant at 1% and 5% levels, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.41 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.1 percent in the likelihood of occurrence of process innovation.

Table 205: Regression Results of PDRI5 and PCRI5 Models – HEI

Variable Name	PDRI5			PCRI5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extfrgrdint</i>	3.3212	0.946	0.8832	1.0923	0.783	0.2791
<i>rdperint</i>	-0.3315	0.437	-0.0882	0.2910	0.380	0.0744
<i>IntoverD</i>	0.0530	0.301	0.0141	0.1724	0.000 ***	0.0441
<i>HHI</i>	2.5901	0.103	0.6888	0.1232	0.936	0.0315
<i>phd_ma</i>	0.0404	0.001 ***	0.0107	0.0027	0.477	0.0007
<i>ipicsec</i>	0.0010	0.570	0.0003	0.0038	0.030 **	0.0010

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI5: Wald chi2(6)=24.33 Prob > chi2=0.0005

For PCRI5: Wald chi2(6)=22.06 Prob > chi2=0.0012

According to the analysis of Turkish manufacturing industry with high education intensity, there are many findings in terms of product innovation. These are:

- R&D expenditure variables except total and internal are not statistically significant at 10% level. Total and *internal R&D expenditures* have positive effects on the likelihood of occurrence of product innovation. It means that more total and *internal R&D expenditures* increase the likelihood of occurrence of product innovation. The most effective expenditure type is *internal R&D expenditure*.
- R&D intensity variables are not statistically significant at 10% level.

- According to PDRE1 and PDRI1 models, the *number of highly educated R&D personnel* is statistically significant and has positive effect on the likelihood of occurrence of product innovation. It means that more highly educated R&D personnel increase the likelihood of occurrence of product innovation.

According to the analysis of Turkish manufacturing industry with high education intensity, there are many findings in terms of process innovation. These are:

- R&D expenditure are not statistically significant at 10% level.
- R&D intensity variables except external and external-domestic are not statistically significant at 10% level. External and external-domestic R&D intensities are statistically significant and have positive effect on the likelihood of occurrence of process innovation. It means that more external and external-domestic R&D intensities increase the likelihood of occurrence of process innovation. The most effective intensity type is *external R&D intensity*.
- According to PCRE1 model, *industrial production index by manufacturing industry* is statistically significant and has positive effect on the likelihood of occurrence of process innovation. According to PCRI1 models, *turnover* and *industrial production index by manufacturing industry* are statistically significant and have positive effects on the likelihood of occurrence of process innovation. It means that more *turnover* and more *industrial production index by manufacturing industry* increase the likelihood of occurrence of process innovation.

Results of the analyses are also viewed by comparing product and process innovation in terms of Turkish manufacturing industry with high education intensity. These are:

- *Total* and *internal R&D expenditure* affect only the likelihood of occurrence of product innovation positively.

- *External and external-domestic R&D intensity* affect only the likelihood of occurrence of process innovation positively.

5.2.2. Manufacturing Industries with Medium-High Education Intensity (MHEI)

Firms that are engaged in R&D in Turkish manufacturing industry with medium-high education intensity are analyzed by with twenty models such as 10 product innovation models and 10 process innovation models, which are shown in Table 3 that is in Chapter 3 and in Appendix 7, 8, 9, and 10.

Regression results of PDRE1 and PCRE1 models include coefficient, p-value, and average marginal effect, which are shown in Table 206. These models analyze the effect of *total R&D expenditure* on the probability of product and process innovations, respectively.

Table 206: Regression Results of PDRE1 and PCRE1 Models – MHEI

Variable Name	PDRE1			PCRE1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>lntrdexpD</i>	0.0757	0.082 *	0.0246	0.0672	0.081 *	0.0211
<i>rdperint</i>	0.9169	0.049 **	0.2978	0.6587	0.204	0.2065
<i>IntoverD</i>	0.0705	0.191	0.0229	0.1381	0.007 ***	0.0433
<i>HHI</i>	-6.5695	0.115	-2.1339	1.8217	0.657	0.5712
<i>phd_ma</i>	0.0013	0.628	0.0004	-0.0002	0.944	-0.0001
<i>ipicsec</i>	-0.0006	0.625	-0.0002	0.0026	0.025 **	0.0008

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE1: Wald chi2(6)=21.86 Prob > chi2=0.0013

For PCRE1: Wald chi2(6)=36.29 Prob > chi2=0.0000

The PDRE1 model focuses on the relationship between product innovation and *total R&D expenditure*, which is shown in Table 206. In this model, independent variables are not statistically significant at 10% level, except *total R&D expenditure* and *R&D personnel intensity*. *Total R&D expenditure* and *R&D personnel intensity* are statistically significant at the 10% and 5% level, respectively. Hence, the null hypothesis, $H1_0$, is rejected. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *total R&D expenditure*, on average, leads to an increase of 2.46 percent in the likelihood of occurrence of product innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.3 in the likelihood of occurrence of product innovation.

The PCRE1 model focuses on the relationship between process innovation and *total R&D expenditure*, which is shown in Table 206. In this model, independent variables are not statistically significant at 10% level, except *total R&D expenditure*, *turnover*, and *industrial production index by manufacturing industry*. *Total R&D expenditure* is statistically significant at the 10% level. Hence, the null hypothesis, H_{30} , is rejected. The *turnover* and *industrial production index by manufacturing industry* are statistically significant at 1% and 5% level, respectively.

- 1 percent increase in the value of *total R&D expenditure*, on average, leads to an increase of 2.11 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.33 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.08 percent in the likelihood of occurrence of process innovation.

Regression results of PDRE2 and PCRE2 models include coefficient, p-value, and average marginal effect, which are shown in Table 207. These models analyze the effect of *internal R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE2 model focuses on the relationship between product innovation and *internal R&D expenditure*, which is shown in Table 207. In this model, independent variables are not statistically significant at 10% level, except *internal R&D expenditure* and *R&D personnel intensity*. *Internal R&D expenditure* and *R&D personnel intensity* are statistically significant at the 10% and 5% level, respectively.

Hence, the null hypothesis, $H1a_0$, is rejected. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *internal R&D expenditure*, on average, leads to an increase of 2.35 percent in the likelihood of occurrence of product innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.3 in the likelihood of occurrence of product innovation.

Table 207: Regression Results of PDRE2 and PCRE2 Models – MHEI

Variable Name	PDRE2			PCRE2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntintrdexpD</i>	0.0723	0.095 *	0.0235	0.0678	0.076 *	0.0213
<i>rdperint</i>	0.9268	0.048 **	0.3013	0.6515	0.208	0.2043
<i>IntoverD</i>	0.0725	0.181	0.0236	0.1373	0.007 ***	0.0431
<i>HHI</i>	-6.4357	0.122	-2.0922	1.9261	0.639	0.6039
<i>phd_ma</i>	0.0014	0.618	0.0005	-0.0002	0.932	-0.0001
<i>ipicsec</i>	-0.0005	0.634	-0.0002	0.0027	0.025 **	0.0008

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE2: Wald $\chi^2(6) = 21.71$ Prob > $\chi^2 = 0.0014$

For PCRE2: Wald $\chi^2(6) = 36.48$ Prob > $\chi^2 = 0.0000$

The PCRE2 model focuses on the relationship between process innovation and *internal R&D expenditure*, which is shown in Table 207. In this model, independent variables are not statistically significant at 10% level, except *internal R&D expenditure*, *turnover*, and *industrial production index by manufacturing industry*. *Internal R&D expenditure* is statistically significant at the 10% level. Hence, the null hypothesis, $H3a_0$, is rejected. The *turnover* and *industrial production index by manufacturing industry* are statistically significant at 1% and 5% level, respectively.

- 1 percent increase in the value of *internal R&D expenditure*, on average, leads to an increase of 2.13 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.31 percent in the likelihood of occurrence of process innovation.

- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.08 percent in the likelihood of occurrence of process innovation.

Regression results of PDRE3 and PCRE3 models include coefficient, p-value, and average marginal effect, which are shown in Table 208. These models analyze the effect of *external R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE3 model focuses on the relationship between product innovation and *external R&D expenditure*, which is shown in Table 208. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity* and *turnover*. Hence, the null hypothesis, $H1b_0$, is not rejected. *R&D personnel intensity* and *turnover* are statistically significant at the 1% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.42 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.04 percent in the likelihood of occurrence of product innovation.

The PCRE3 model focuses on the relationship between process innovation and *external R&D expenditure*, which is shown in Table 208. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity*, *turnover*, and *industrial production index by manufacturing industry*. Hence, the null hypothesis, $H3b_0$, is rejected. *R&D personnel intensity*, *turnover*, and *industrial production index by manufacturing industry* are statistically significant at 10%, 1%, and 5% level, respectively.

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.31 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.96 percent in the likelihood of occurrence of process innovation.

- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.09 percent in the likelihood of occurrence of process innovation.

Table 208: Regression Results of PDRE3 and PCRE3 Models – MHEI

Variable Name	PDRE3			PCRE3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpD</i>	0.0036	0.693	0.0012	-0.0043	0.679	-0.0014
<i>rdperint</i>	1.2958	0.004 ***	0.4249	0.9676	0.068 *	0.3062
<i>IntoverD</i>	0.1233	0.002 ***	0.0404	0.1882	0.000 ***	0.0596
<i>HHI</i>	-5.9375	0.147	-1.9471	2.6514	0.516	0.8390
<i>phd_ma</i>	0.0030	0.433	0.0010	0.0013	0.692	0.0004
<i>ipicsec</i>	-0.0003	0.773	-0.0001	0.0028	0.015 **	0.0009

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE3: Wald chi2(6)=18.04 Prob > chi2=0.0061

For PCRE3: Wald chi2(6)=33.79 Prob > chi2=0.0000

Regression results of PDRE4 and PCRE4 models include coefficient, p-value, and average marginal effect, which are shown in Table 209. These models analyze the effect of *external-domestic R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE4 model focuses on the relationship between product innovation and *external-domestic R&D expenditure*, which is shown in Table 209. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity* and *turnover*. Hence, the null hypothesis, $H1c_0$, is not rejected. *R&D personnel intensity* and *turnover* are statistically significant at the 1% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.42 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.02 percent in the likelihood of occurrence of product innovation.

The PCRE4 model focuses on the relationship between process innovation and *external-domestic R&D expenditure*, which is shown in Table 209. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity*, *turnover*, and *industrial production index by manufacturing*

industry. Hence, the null hypothesis, $H3c_0$, is rejected. *R&D personnel intensity*, *turnover*, and *industrial production index by manufacturing industry* are statistically significant at 10%, 1%, and 5% level, respectively.

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.31 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.96 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.09 percent in the likelihood of occurrence of process innovation.

Table 209: Regression Results of PDRE4 and PCRE4 Models – MHEI

Variable Name	PDRE4			PCRE4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpdomD</i>	0.0054	0.562	0.0018	-0.0043	0.695	-0.0014
<i>rdperint</i>	1.2925	0.004 ***	0.4238	0.9694	0.068 *	0.3067
<i>IntoverD</i>	0.1226	0.002 ***	0.0402	0.1884	0.000 ***	0.0596
<i>HHI</i>	-5.9022	0.151	-1.9352	2.5860	0.525	0.8181
<i>phd_ma</i>	0.0030	0.433	0.0010	0.0012	0.692	0.0004
<i>ipicsec</i>	-0.0003	0.773	-0.0001	0.0028	0.015 **	0.0009

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE4: Wald $\chi^2(6) = 18.10$ Prob > $\chi^2 = 0.0060$

For PCRE4: Wald $\chi^2(6) = 33.86$ Prob > $\chi^2 = 0.0000$

Regression results of PDRE5 and PCRE5 models include coefficient, p-value, and average marginal effect, which are shown in Table 210. These models analyze the effect of *external-foreign R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE5 model focuses on the relationship between product innovation and *external-foreign R&D expenditure*, which is shown in Table 210. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity* and *turnover*. Hence, the null hypothesis, $H1d_0$, is not rejected. *R&D personnel intensity* and *turnover* are statistically significant at the 1% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.42 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.14 percent in the likelihood of occurrence of product innovation.

Table 210: Regression Results of PDRE5 and PCRE5 Models – MHEI

Variable Name	PDRE5			PCRE5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpforD</i>	-0.0126	0.461	-0.0041	0.0043	0.790	0.0014
<i>rdperint</i>	1.2929	0.004 ***	0.4249	0.9621	0.068 *	0.3039
<i>IntoverD</i>	0.1261	0.002 ***	0.0414	0.1864	0.000 ***	0.0589
<i>HHI</i>	-5.5480	0.180	-1.8234	2.4087	0.553	0.7608
<i>phd_ma</i>	0.0032	0.437	0.0011	0.0012	0.691	0.0004
<i>ipicsec</i>	-0.0004	0.737	-0.0001	0.0028	0.015 **	0.0009

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE5: Wald chi2(6)=17.56 Prob > chi2=0.0074

For PCRE5: Wald chi2(6)=34.26 Prob > chi2=0.0000

The PCRE5 model focuses on the relationship between process innovation and *external-foreign R&D expenditure*, which is shown in Table 210. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity*, *turnover*, and *industrial production index by manufacturing industry*. Hence, the null hypothesis, H_{3c0} , is rejected. *R&D personnel intensity*, *turnover*, and *industrial production index by manufacturing industry* are statistically significant at 10%, 1%, and 5% level, respectively.

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.3 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.89 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.09 percent in the likelihood of occurrence of process innovation.

Regression results of PDRI1 and PCRI1 models include coefficient, p-value, and average marginal effect, which are shown in Table 211. These models analyze the

effect of *total R&D intensity* on the probability of product and process innovations, respectively.

Table 211: Regression Results of PDRI1 and PCRI1 Models – MHEI

Variable Name	PDRI1			PCRI1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>totrdint</i>	0.1235	0.683	0.0405	0.2182	0.510	0.0689
<i>rdperint</i>	1.2301	0.022 **	0.4035	0.8378	0.178	0.2646
<i>IntoverD</i>	0.1255	0.002 ***	0.0412	0.1888	0.000 ***	0.0596
<i>HHI</i>	-5.9029	0.153	-1.9364	2.4360	0.550	0.7693
<i>phd_ma</i>	0.0029	0.434	0.0010	0.0011	0.719	0.0003
<i>ipicsec</i>	-0.0004	0.750	-0.0001	0.0028	0.016 **	0.0689

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI1: Wald chi2(6)=17.49 Prob > chi2=0.0076

For PCRI1: Wald chi2(6)=33.58 Prob > chi2=0.0000

The PDRI1 model focuses on the relationship between product innovation and *total R&D intensity*, which is shown in Table 211. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity* and *turnover*. Hence, the null hypothesis, H_{20} , is not rejected. *R&D personnel intensity* and *turnover* are statistically significant at 5% and 1% levels, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.4 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.12 percent in the likelihood of occurrence of product innovation.

The PCRI1 model focuses on the relationship between process innovation and *total R&D intensity*, which is shown in Table 211. In this model, independent variables are not statistically significant at 10% level, except *turnover* and *industrial production index by manufacturing industry*. Hence, the null hypothesis, H_{40} , is not rejected. The *turnover* and *industrial production index by manufacturing industry* are statistically significant at 1% and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.96 percent in the likelihood of occurrence of process innovation.

- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 6.89 percent in the likelihood of occurrence of process innovation.

Regression results of PDRI2 and PCRI2 models include coefficient, p-value, and average marginal effect, which are shown in Table 212. These models analyze the effect of *internal R&D intensity* on the probability of product and process innovations, respectively.

Table 212: Regression Results of PDRI2 and PCRI2 Models – MHEI

Variable Name	PDRI2			PCRI2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>intrdint</i>	0.0264	0.937	0.0087	0.1704	0.657	0.0538
<i>rdperint</i>	1.2845	0.019 **	0.4215	0.8723	0.171	0.2756
<i>IntoverD</i>	0.1246	0.002 ***	0.0409	0.1883	0.000 ***	0.0595
<i>HHI</i>	-5.8646	0.155	-1.9245	2.4700	0.544	0.7802
<i>phd_ma</i>	0.0030	0.427	0.0010	0.0011	0.712	0.0004
<i>ipicsec</i>	-0.0003	0.758	-0.0001	0.0028	0.016 **	0.0009

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI2: Wald chi2(6)=17.66 Prob > chi2=0.0071

For PCRI2: Wald chi2(6)=33.91 Prob > chi2=0.0000

The PDRI2 model focuses on the relationship between product innovation and *internal R&D intensity*, which is shown in Table 212. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity* and *turnover*. Hence, the null hypothesis, $H2a_0$, is not rejected. *R&D personnel intensity* and *turnover* are statistically significant at 5% and 1% levels, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.42 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.09 percent in the likelihood of occurrence of product innovation.

The PCRI2 model focuses on the relationship between process innovation and *internal R&D intensity*, which is shown in Table 212. In this model, independent variables are not statistically significant at 10% level, except *turnover* and *industrial production index by manufacturing industry*. Hence, the null hypothesis, $H4a_0$, is not

rejected. The *turnover* and *industrial production index by manufacturing industry* are statistically significant at 1% and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.95 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.09 percent in the likelihood of occurrence of process innovation.

Regression results of PDRI3 and PCRI3 models include coefficient, p-value, and average marginal effect, which are shown in Table 213. These models analyze the effect of *external R&D intensity* on the probability of product and process innovations, respectively.

Table 213: Regression Results of PDRI3 and PCRI3 Models – MHEI

Variable Name	PDRI3			PCRI3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extrdint</i>	2.3185	0.144	0.7601	1.5119	0.208	0.4776
<i>rdperint</i>	1.2641	0.006 ***	0.4144	0.9220	0.087 *	0.2913
<i>IntoverD</i>	0.1263	0.002 ***	0.0414	0.1879	0.000 ***	0.0594
<i>HHI</i>	-6.0178	0.144	-1.9730	2.3587	0.562	0.7452
<i>phd_ma</i>	0.0031	0.425	0.0010	0.0013	0.670	0.0004
<i>ipicsec</i>	-0.0004	0.753	-0.0001	0.0028	0.016 **	0.0009

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI3: Wald chi2(6)=18.25 Prob > chi2=0.0056

For PCRI3: Wald chi2(6)=35.64 Prob > chi2=0.0000

The PDRI3 model focuses on the relationship between product innovation and *external R&D intensity*, which is shown in Table 213. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity* and *turnover*. Hence, the null hypothesis, $H2b_0$, is not rejected. *R&D personnel intensity* and *turnover* are statistically significant at the 1% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.41 in the likelihood of occurrence of product innovation.

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.14 percent in the likelihood of occurrence of product innovation.

The PCRI3 model focuses on the relationship between process innovation and *external R&D intensity*, which is shown in Table 213. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity*, *turnover*, and *industrial production index by manufacturing industry*. Hence, the null hypothesis, $H4b_0$, is not rejected. *R&D personnel intensity*, *turnover*, and *industrial production index by manufacturing industry* are statistically significant at 10%, 1%, and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.29 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.94 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.09 percent in the likelihood of occurrence of process innovation.

Regression results of PDRI4 and PCRI4 models include coefficient, p-value, and average marginal effect, which are shown in Table 214. These models analyze the effect of *external-domestic R&D intensity* on the probability of product and process innovations, respectively.

The PDRI4 model focuses on the relationship between product innovation and *external-domestic R&D intensity*, which is shown in Table 214. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity* and *turnover*. Hence, the null hypothesis, $H2c_0$, is not rejected. *R&D personnel intensity* and *turnover* are statistically significant at the 1% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.42 in the likelihood of occurrence of product innovation.

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.14 percent in the likelihood of occurrence of product innovation.

Table 214: Regression Results of PDRI4 and PCRI4 Models – MHEI

Variable Name	PDRI4			PCRI4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extdomrdint</i>	2.5616	0.171	0.8401	1.0504	0.322	0.3319
<i>rdperint</i>	1.2669	0.006 ***	0.4155	0.9252	0.086 *	0.2924
<i>IntoverD</i>	0.1261	0.002 ***	0.0414	0.1874	0.000 ***	0.0592
<i>HHI</i>	-5.9948	0.146	-1.9661	2.4306	0.550	0.7681
<i>phd_ma</i>	0.0031	0.426	0.0010	0.0013	0.671	0.0004
<i>ipicsec</i>	-0.0004	0.754	-0.0001	0.0028	0.016 **	0.0009

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI4: Wald chi2(6)=18.04 Prob > chi2=0.0061

For PCRI4: Wald chi2(6)=35.38 Prob > chi2=0.0000

The PCRI4 model focuses on the relationship between process innovation and *external-domestic R&D intensity*, which is shown in Table 214. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity*, *turnover*, and *industrial production index by manufacturing industry*. Hence, the null hypothesis, $H4c_0$, is not rejected. *R&D personnel intensity*, *turnover*, and *industrial production index by manufacturing industry* are statistically significant at 10%, 1%, and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.29 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.92 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.09 percent in the likelihood of occurrence of process innovation.

Regression results of PDRI5 and PCRI5 models include coefficient, p-value, and average marginal effect, which are shown in Table 215. These models analyze the effect of *external-foreign R&D intensity* on the probability of product and process innovations, respectively.

The PDRI5 model focuses on the relationship between product innovation and *external-foreign R&D intensity*, which is shown in Table 215. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity* and *turnover*. Hence, the null hypothesis, $H2d_0$, is not rejected. *R&D personnel intensity* and *turnover* are statistically significant at the 1% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.43 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.11 percent in the likelihood of occurrence of product innovation.

Table 215: Regression Results of PDRI5 and PCRI5 Models – MHEI

Variable Name	PDRI5			PCRI5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extfrgrdint</i>	4.8263	0.222	1.5826	18.805	0.006 ***	5.9267
<i>rdperint</i>	1.2984	0.004 ***	0.4258	0.9769	0.067 *	0.3079
<i>lntoverD</i>	0.1254	0.002 ***	0.0411	0.1893	0.000 ***	0.0596
<i>HHI</i>	-5.9529	0.148	-1.9520	2.0778	0.608	0.6549
<i>phd_ma</i>	0.0030	0.430	0.0010	0.0012	0.687	0.0004
<i>ipicsec</i>	-0.0003	0.761	-0.0001	0.0028	0.015 **	0.0009

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI5: Wald $\chi^2(6) = 18.24$ Prob > $\chi^2 = 0.0057$

For PCRI5: Wald $\chi^2(6) = 37.13$ Prob > $\chi^2 = 0.0000$

The PCRI5 model focuses on the relationship between process innovation and *external-foreign R&D intensity*, which is shown in Table 215. In this model, independent variables such as *external-foreign R&D intensity*, *R&D personnel intensity*, *turnover*, and *industrial production index by manufacturing industry* are statistically significant 1%, 10%, 1%, and 5% levels, respectively. Hence, the null hypothesis, $H4d_0$, is rejected. The rest of the independent variables are not statistically significant at 10%. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external-foreign R&D intensity*, on average, leads to an increase of 5.93 in the likelihood of occurrence of process innovation.

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.31 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.96 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.09 percent in the likelihood of occurrence of process innovation.

According to the analysis of Turkish manufacturing industry with medium-high education intensity, there are many findings in terms of product innovation. These are:

- R&D expenditure variables except total and internal are not statistically significant at 10% level. *Total* and *internal R&D expenditures* have positive effects on the likelihood of occurrence of product innovation. It means that more *total* and *internal R&D expenditures* increase the likelihood of occurrence of product innovation. The most effective expenditure type is *total R&D expenditure*.
- R&D intensity variables are not statistically significant at 10% level.
- According to PDRE1 model, *R&D personnel intensity* is statistically significant and has positive effect on the likelihood of occurrence of product innovation. According to PDRI1 model, *R&D personnel intensity* and *turnover* are statistically significant and have positive effects on the likelihood of occurrence of product innovation. It means that more *R&D personnel intensity* and more *turnover* increase the likelihood of occurrence of product innovation.

According to the analysis of Turkish manufacturing industry with medium-high education intensity, there are many findings in terms of process innovation. These are:

- R&D expenditure variables except total and internal are not statistically significant at 10% level. *Total* and *internal R&D expenditures* are statistically significant and have positive effects on the likelihood of occurrence of process innovation. It means that more *total* and *internal R&D expenditures* increase the likelihood of occurrence of process innovation. The most effective expenditure type is *internal R&D expenditure*.
- R&D intensity variables except external-foreign are not statistically significant at 10% level. *External-foreign R&D intensity* is statistically significant and has positive effect on the likelihood of occurrence of process innovation. It means that more *external-foreign R&D intensity* increases the likelihood of occurrence of process innovation.
- According to PCRE1 and PCRI1 models, *turnover* and *industrial production index by manufacturing industry* are statistically significant and have positive effects on the likelihood of occurrence of process innovation. It means that more *turnover* and more *industrial production index by manufacturing industry* increase the likelihood of occurrence of process innovation.

Results of the analyses are also viewed by comparing product and process innovation in terms of Turkish manufacturing industry with medium-high education intensity. These are:

- The impact of *total* and *internal R&D expenditure* on the likelihood of occurrence of product innovation are greater than their impacts on the likelihood of occurrence of process innovation.
- *External-foreign R&D intensity* affects only the likelihood of occurrence of process innovation positively.

5.2.3. Manufacturing Industries with Medium-Low Education Intensity (MLEI)

Firms that are engaged in R&D in Turkish manufacturing industry with medium-low education intensity are analyzed by with twenty models such as 10 product innovation models and 10 process innovation models, which are shown in Table 3 that is in Chapter 3 and in Appendix 7, 8, 9, and 10.

Regression results of PDRE1 and PCRE1 models include coefficient, p-value, and average marginal effect, which are shown in Table 216. These models analyze the effect of *total R&D expenditure* on the probability of product and process innovations, respectively.

Table 216: Regression Results of PDRE1 and PCRE1 Models – MLEI

Variable Name	PDRE1			PCRE1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntrdexpD</i>	0.1518	0.000 ***	0.0517	0.0866	0.013 **	0.0278
<i>rdperint</i>	0.2105	0.326	0.0718	1.6215	0.027 **	0.5202
<i>IntoverD</i>	0.0713	0.093 *	0.0243	0.1687	0.000 ***	0.0541
<i>HHI</i>	-37.156	0.000 ***	-12.664	-11.849	0.193	-3.8014
<i>phd_ma</i>	-0.0092	0.321	-0.0031	-0.0063	0.559	-0.0020
<i>ipicsec</i>	0.0002	0.935	0.0001	0.0008	0.726	0.0003

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE1: Wald chi2(6)=51.29 Prob > chi2=0.0000

For PCRE1: Wald chi2(6)=37.45 Prob > chi2=0.0000

The PDRE1 model focuses on the relationship between product innovation and *total R&D expenditure*, which is shown in Table 216. In this model, independent variables are not statistically significant at 10% level, except *total R&D expenditure*, *turnover*, and *HHI*. *Total R&D expenditure*, *HHI*, and *turnover* are statistically significant at the 1%, 10%, 1% level, respectively. Hence, the null hypothesis, $H1_0$, is rejected. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *total R&D expenditure*, on average, leads to an increase of 5.17 percent in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 2.43 percent in the likelihood of occurrence of product innovation.

- An increase in *HHI* of 0.01, on average, leads to a decrease of 12.66 in the likelihood of occurrence of product innovation.

The PCRE1 model focuses on the relationship between process innovation and *total R&D expenditure*, which is shown in Table 216. In this model, independent variables are not statistically significant at 10% level, except *total R&D expenditure*, *R&D personnel intensity*, and *turnover*. *Total R&D expenditure* is statistically significant at the 5% level. Hence, the null hypothesis, $H3_0$, is rejected. *R&D personnel intensity* and *turnover* are statistically significant at 5% and 1% levels, respectively.

- 1 percent increase in the value of *total R&D expenditure*, on average, leads to an increase of 2.78 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.52 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.41 percent in the likelihood of occurrence of process innovation.

Regression results of PDRE2 and PCRE2 models include coefficient, p-value, and average marginal effect, which are shown in Table 217. These models analyze the effect of *internal R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE2 model focuses on the relationship between product innovation and *internal R&D expenditure*, which is shown in Table 217. In this model, independent variables are not statistically significant at 10% level, except *internal R&D expenditure*, *turnover*, and *HHI*. *Internal R&D expenditure*, *HHI*, and *turnover* are statistically significant at the 1%, 10%, 1% level, respectively. Hence, the null hypothesis, $H1a_0$, is rejected. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *internal R&D expenditure*, on average, leads to an increase of 5.02 percent in the likelihood of occurrence of product innovation.

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 2.56 percent in the likelihood of occurrence of product innovation.
- An increase in *HHI* of 0.01, on average, leads to a decrease of 12.07 in the likelihood of occurrence of product innovation.

Table 217: Regression Results of PDRE2 and PCRE2 Models – MLEI

Variable Name	PDRE2			PCRE2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntintrdexpD</i>	0.1472	0.000 ***	0.0502	0.0868	0.014 **	0.0278
<i>rdperint</i>	0.2250	0.297	0.0768	1.6116	0.028 **	0.5172
<i>IntoverD</i>	0.0749	0.077 *	0.0256	0.1691	0.000 ***	0.0543
<i>HHI</i>	-37.224	0.000 ***	-12.704	-11.864	0.192	-3.8075
<i>phd_ma</i>	-0.0089	0.338	-0.0030	-0.0064	0.554	-0.0021
<i>ipicsec</i>	0.0002	0.934	0.0001	0.0008	0.723	0.0003

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE2: Wald $\chi^2(6)=49.33$ Prob > $\chi^2=0.0000$

For PCRE2: Wald $\chi^2(6)=37.42$ Prob > $\chi^2=0.0000$

The PCRE2 model focuses on the relationship between process innovation and *internal R&D expenditure*, which is shown in Table 217. In this model, independent variables are not statistically significant at 10% level, except *internal R&D expenditure*, *R&D personnel intensity*, and *turnover*. *Internal R&D expenditure* is statistically significant at the 5% level. Hence, the null hypothesis, $H3a_0$, is rejected. *R&D personnel intensity* and *turnover* are statistically significant at 5% and 1% levels, respectively.

- 1 percent increase in the value of *total R&D expenditure*, on average, leads to an increase of 2.78 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.52 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.43 percent in the likelihood of occurrence of process innovation.

Regression results of PDRE3 and PCRE3 models include coefficient, p-value, and average marginal effect, which are shown in Table 218. These models analyze the

effect of *external R&D expenditure* on the probability of product and process innovations, respectively.

Table 218: Regression Results of PDRE3 and PCRE3 Models – MLEI

Variable Name	PDRE3			PCRE3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpD</i>	0.0131	0.086 *	0.0046	-0.0008	0.927	-0.0003
<i>rdperint</i>	0.7976	0.003 ***	0.2781	2.3998	0.003 ***	0.7778
<i>IntoverD</i>	0.1405	0.001 ***	0.0490	0.2169	0.000 ***	0.0703
<i>HHI</i>	-36.889	0.000 ***	-12.862	-12.526	0.173	-4.0597
<i>phd_ma</i>	0.0059	0.521	0.0021	0.0025	0.821	0.0008
<i>ipicsec</i>	0.0006	0.737	0.0002	0.0010	0.666	0.0003

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE3: Wald chi2(6)=31.78 Prob > chi2=0.0000

For PCRE3: Wald chi2(6)=30.75 Prob > chi2=0.0000

The PDRE3 model focuses on the relationship between product innovation and *external R&D expenditure*, which is shown in Table 218. In this model, *external R&D expenditure* is statistically significant at the 10% level. Hence, the null hypothesis, $H1b_0$, is rejected. *R&D personnel intensity*, *turnover*, and *HHI* are statistically significant at 1% level. The rest of the independent variables are not statistically significant at 10% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *external R&D expenditure*, on average, leads to an increase of 0.46 percent in the likelihood of occurrence of product innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.28 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.9 percent in the likelihood of occurrence of product innovation.
- An increase in *HHI* of 0.01, on average, leads to a decrease of 12.86 in the likelihood of occurrence of product innovation.

The PCRE3 model focuses on the relationship between process innovation and *external R&D expenditure*, which is shown in Table 218. In this model, independent

variables are not statistically significant at 10% level, except *R&D personnel intensity* and *turnover*. Hence, the null hypothesis, $H3b_0$, is not rejected. *R&D personnel intensity* and *turnover* are statistically significant at the 1% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.78 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 7.03 percent in the likelihood of occurrence of process innovation.

Regression results of PDRE4 and PCRE4 models include coefficient, p-value, and average marginal effect, which are shown in Table 219. These models analyze the effect of *external-domestic R&D expenditure* on the probability of product and process innovations, respectively.

Table 219: Regression Results of PDRE4 and PCRE4 Models – MLEI

Variable Name	PDRE4			PCRE4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpdomD</i>	0.0083	0.289	0.0029	-0.0062	0.471	-0.0020
<i>rdperint</i>	0.8633	0.003 ***	0.3014	2.4126	0.002 ***	0.7818
<i>IntoverD</i>	0.1424	0.000 ***	0.0497	0.2173	0.000 ***	0.0704
<i>HHI</i>	-37.033	0.000 ***	-12.927	-12.630	0.170	-4.0928
<i>phd_ma</i>	0.0062	0.506	0.0022	0.0026	0.811	0.0008
<i>ipicsec</i>	0.0006	0.767	0.0002	0.0010	0.670	0.0003

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE4: Wald chi2(6)=29.71 Prob > chi2=0.0000

For PCRE4: Wald chi2(6)=30.82 Prob > chi2=0.0000

The PDRE4 model focuses on the relationship between product innovation and *external-domestic R&D expenditure*, which is shown in Table 219. In this model, *R&D personnel intensity*, *turnover*, and *HHI* are statistically significant at 1% level. The rest of the independent variables are not statistically significant at 10% level. Hence, the null hypothesis, $H1c_0$, is not rejected. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.3 in the likelihood of occurrence of product innovation.

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.97 percent in the likelihood of occurrence of product innovation.
- An increase in *HHI* of 0.01, on average, leads to a decrease of 12.93 in the likelihood of occurrence of product innovation.

The PCRE4 model focuses on the relationship between process innovation and *external-domestic R&D expenditure*, which is shown in Table 219. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity* and *turnover*. Hence, the null hypothesis, $H3c_0$, is not rejected. *R&D personnel intensity* and *turnover* are statistically significant at the 1% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.78 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 7.04 percent in the likelihood of occurrence of process innovation.

Regression results of PDRE5 and PCRE5 models include coefficient, p-value, and average marginal effect, which are shown in Table 220. These models analyze the effect of *external-foreign R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE5 model focuses on the relationship between product innovation and *external-foreign R&D expenditure*, which is shown in Table 220. In this model, *external-foreign R&D expenditure* is statistically significant at the 5% level. Hence, the null hypothesis, $H1d_0$, is rejected. *R&D personnel intensity*, *turnover*, and *HHI* are statistically significant at 1% level. The rest of the independent variables are not statistically significant at 10% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *external-foreign R&D expenditure*, on average, leads to an increase of 1.26 percent in the likelihood of occurrence of product innovation.

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.3 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.86 percent in the likelihood of occurrence of product innovation.
- An increase in *HHI* of 0.01, on average, leads to a decrease of 12.83 in the likelihood of occurrence of product innovation.

Table 220: Regression Results of PDRE5 and PCRE5 Models – MLEI

Variable Name	PDRE5			PCRE5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpforD</i>	0.0361	0.012 **	0.0126	0.0303	0.136	0.0098
<i>rdperint</i>	0.8722	0.002 ***	0.3040	2.3252	0.003 ***	0.7522
<i>IntoverD</i>	0.1396	0.001 ***	0.0486	0.2143	0.000 ***	0.0693
<i>HHI</i>	-36.820	0.000 ***	-12.832	-12.066	0.188	-3.9034
<i>phd_ma</i>	0.0039	0.676	0.0014	0.0001	0.991	0.00004
<i>ipicsec</i>	0.0007	0.697	0.0003	0.0012	0.588	0.0004

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE5: Wald $\chi^2(6)=33.93$ Prob > $\chi^2=0.0000$

For PCRE5: Wald $\chi^2(6)=34.82$ Prob > $\chi^2=0.0000$

The PCRE5 model focuses on the relationship between process innovation and *external-foreign R&D expenditure*, which is shown in Table 218. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity* and *turnover*. Hence, the null hypothesis, $H3d_0$, is not rejected. *R&D personnel intensity* and *turnover* are statistically significant at the 1% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.75 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 7.11 percent in the likelihood of occurrence of process innovation.

Regression results of PDRI1 and PCRI1 models include coefficient, p-value, and average marginal effect, which are shown in Table 221. These models analyze the effect of *total R&D intensity* on the probability of product and process innovations, respectively.

The PDRI1 model focuses on the relationship between product innovation and *total R&D intensity*, which is shown in Table 221. In this model, independent variables are not statistically significant at the 10% level, except *turnover* and *HHI*. Hence, the null hypothesis, H_{20} , is not rejected. *Turnover* and *HHI* are statistically significant at the 1% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.72 percent in the likelihood of occurrence of product innovation.
- An increase in *HHI* of 0.01, on average, leads to a decrease of 12.7 in the likelihood of occurrence of product innovation.

Table 221: Regression Results of PDRI1 and PCRI1 Models – MLEI

Variable Name	PDRI1			PCRI1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>totrdint</i>	3.4527	0.124	1.1950	0.4005	0.721	0.1296
<i>rdperint</i>	0.3694	0.668	0.1278	2.3562	0.036 **	0.7627
<i>IntoverD</i>	0.1652	0.000 ***	0.0572	0.2196	0.000 ***	0.0711
<i>HHI</i>	-36.698	0.000 ***	-12.701	-12.458	0.176	-4.0327
<i>phd_ma</i>	0.0049	0.607	0.0017	0.0021	0.846	0.0007
<i>ipicsec</i>	0.0006	0.753	0.0002	0.0010	0.663	0.0003

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI1: Wald $\chi^2(6)=24.88$ Prob > $\chi^2=0.0000$

For PCRI1: Wald $\chi^2(6)=89.81$ Prob > $\chi^2=0.0000$

The PCRI1 model focuses on the relationship between process innovation and *total R&D intensity*, which is shown in Table 221. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity* and *turnover*. Hence, the null hypothesis, H_{40} , is not rejected. *R&D personnel intensity* and *turnover* are statistically significant at 5% and 1% levels, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.76 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 7.11 percent in the likelihood of occurrence of process innovation.

Regression results of PDRI2 and PCRI2 models include coefficient, p-value, and average marginal effect, which are shown in Table 222. These models analyze the effect of *internal R&D intensity* on the probability of product and process innovations, respectively.

Table 222: Regression Results of PDRI2 and PCRI2 Models – MLEI

Variable Name	PDRI2			PCRI2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>intrdint</i>	3.4223	0.169	1.1850	0.3058	0.797	0.0990
<i>rdperint</i>	0.3751	0.669	0.1299	2.3740	0.035 **	0.7686
<i>IntoverD</i>	0.1649	0.000 ***	0.0571	0.2192	0.000 ***	0.0710
<i>HHI</i>	-36.707	0.000 ***	-12.710	-12.486	0.175	-4.0424
<i>phd_ma</i>	0.0049	0.610	0.0017	0.0022	0.841	0.0007
<i>ipicsec</i>	0.0006	0.748	0.0002	0.0010	0.663	0.0003

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI2: Wald chi2(6)=31.69 Prob > chi2=0.0000

For PCRI2: Wald chi2(6)=30.04 Prob > chi2=0.0000

The PDRI2 model focuses on the relationship between product innovation and *internal R&D intensity*, which is shown in Table 222. In this model, independent variables are not statistically significant at the 10% level, except *turnover* and *HHI*. Hence, the null hypothesis, $H2a_0$, is not rejected. *Turnover* and *HHI* are statistically significant at the 1% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.71 percent in the likelihood of occurrence of product innovation.
- An increase in *HHI* of 0.01, on average, leads to a decrease of 12.71 in the likelihood of occurrence of product innovation.

The PCRI2 model focuses on the relationship between process innovation and *internal R&D intensity*, which is shown in Table 222. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity* and *turnover*. Hence, the null hypothesis, $H4a_0$, is not rejected. *R&D personnel intensity* and *turnover* are statistically significant at 5% and 1% levels, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.77 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 7.1 percent in the likelihood of occurrence of process innovation.

Regression results of PDRI3 and PCRI3 models include coefficient, p-value, and average marginal effect, which are shown in Table 223. These models analyze the effect of *external R&D intensity* on the probability of product and process innovations, respectively.

The PDRI3 model focuses on the relationship between product innovation and *external R&D intensity*, which is shown in Table 223. In this model, independent variables such as *external R&D intensity*, *R&D personnel intensity*, *turnover*, and *HHI* are statistically significant at 10%, 5%, 1%, and 1% levels, respectively. The rest of the independent variables are not statistically significant at 10% level. Hence, the null hypothesis, $H2b_0$, is not rejected. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external R&D intensity*, on average, leads to an increase of 19.02 in the likelihood of occurrence of product innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.3 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.25 percent in the likelihood of occurrence of product innovation.
- An increase in *HHI* of 0.01, on average, leads to a decrease of 12.93 in the likelihood of occurrence of product innovation.

The PCRI3 model focuses on the relationship between process innovation and *external R&D intensity*, which is shown in Table 223. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity* and *turnover*. Hence, the null hypothesis, $H4b_0$, is not rejected. *R&D personnel intensity* and *turnover* are statistically significant at 5% and 1% levels, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.78 in the likelihood of occurrence of process innovation.
- A 1 percent increase in the value of *turnover*, on average, leads to an increase of 7.13 percent in the likelihood of occurrence of process innovation.

Table 223: Regression Results of PDRI3 and PCRI3 Models – MLEI

Variable Name	PDRI3			PCRI3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extrdint</i>	54.846	0.054 *	19.020	28.587	0.297	9.2404
<i>rdperint</i>	0.8603	0.014 **	0.2984	2.4455	0.028 **	0.7905
<i>IntoverD</i>	0.1513	0.000 ***	0.0525	0.2206	0.000 ***	0.0713
<i>HHI</i>	-37.292	0.000 ***	-12.933	-12.600	0.171	-4.0730
<i>phd_ma</i>	0.0064	0.504	0.0022	0.0018	0.868	0.0006
<i>ipicsec</i>	0.0006	0.769	0.0002	0.0010	0.677	0.0003

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI3: Wald chi2(6)=34.55 Prob > chi2=0.0000

For PCRI3: Wald chi2(6)=31.83 Prob > chi2=0.0000

Regression results of PDRI4 and PCRI4 models include coefficient, p-value, and average marginal effect, which are shown in Table 224. These models analyze the effect of *external-domestic R&D intensity* on the probability of product and process innovations, respectively.

The PDRI4 model focuses on the relationship between product innovation and *external-domestic R&D intensity*, which is shown in Table 224. In this model, independent variables such as *R&D personnel intensity*, *turnover*, and *HHI* are statistically significant at 5%, 1%, and 1% levels, respectively. The rest of the independent variables are not statistically significant at 10% level. Hence, the null hypothesis, $H2c_0$, is not rejected. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.29 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.15 percent in the likelihood of occurrence of product innovation.

- An increase in *HHI* of 0.01, on average, leads to a decrease of 12.92 in the likelihood of occurrence of product innovation.

Table 224: Regression Results of PDRI4 and PCRI4 Models – MLEI

Variable Name	PDRI4			PCRI4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extdomrdint</i>	27.234	0.258	9.4724	0.0374	0.980	0.0121
<i>rdperint</i>	0.8275	0.014 **	0.2878	2.3921	0.021 **	0.7753
<i>IntoverD</i>	0.1481	0.000 ***	0.0515	0.2167	0.000 ***	0.0702
<i>HHI</i>	-37.153	0.000 ***	-12.922	-12.499	0.174	-4.0508
<i>phd_ma</i>	0.0069	0.470	0.0024	0.0024	0.823	0.0008
<i>ipicsec</i>	0.0006	0.769	0.0002	0.0010	0.666	0.0003

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI4: Wald $\chi^2(6)=31.22$ Prob > $\chi^2=0.0000$

For PCRI4: Wald $\chi^2(6)=97.99$ Prob > $\chi^2=0.0000$

The PCRI4 model focuses on the relationship between process innovation and *external-domestic R&D intensity*, which is shown in Table 224. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity* and *turnover*. Hence, the null hypothesis, $H4c_0$, is not rejected. *R&D personnel intensity* and *turnover* are statistically significant at 5% and 1% levels, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.78 in the likelihood of occurrence of process innovation.
- A 1 percent increase in the value of *turnover*, on average, leads to an increase of 7.02 percent in the likelihood of occurrence of process innovation.

Regression results of PDRI5 and PCRI5 models include coefficient, p-value, and average marginal effect, which are shown in Table 225. These models analyze the effect of *external-foreign R&D intensity* on the probability of product and process innovations, respectively.

The PDRI5 model focuses on the relationship between product innovation and *external-foreign R&D intensity*, which is shown in Table 225. In this model, *external-foreign R&D intensity* is statistically significant at 5% level. Hence, the null hypothesis, $H2d_0$, is rejected. Independent variables such as *R&D personnel intensity*,

turnover, and *HHI* are statistically significant at 1% level. The rest of the independent variables are not statistically significant at 10% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external-foreign R&D intensity*, on average, leads to an increase of 188.5 in the likelihood of occurrence of product innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.3 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.98 percent in the likelihood of occurrence of product innovation.
- An increase in *HHI* of 0.01, on average, leads to a decrease of 12.39 in the likelihood of occurrence of product innovation.

Table 225: Regression Results of PDRI5 and PCRI5 Models – MLE

Variable Name	PDRI5			PCRI5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extfrgrdint</i>	541.55	0.038 **	188.51	348.25	0.393	112.65
<i>rdperint</i>	0.8723	0.002 ***	0.3036	2.2848	0.003 ***	0.7391
<i>IntoverD</i>	0.1431	0.000 ***	0.0498	0.2177	0.000 ***	0.0704
<i>HHI</i>	-35.580	0.000 ***	-12.385	-11.515	0.211	-3.7249
<i>phd_ma</i>	0.0028	0.767	0.0010	-0.0016	0.886	-0.0005
<i>ipicsec</i>	0.0009	0.653	0.0003	0.0014	0.539	0.0004

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI5: Wald chi2(6)=31.89 Prob > chi2=0.0000

For PCRI5: Wald chi2(6)=32.28 Prob > chi2=0.0000

The PCRI5 model focuses on the relationship between process innovation and *external-foreign R&D intensity*, which is shown in Table 225. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity* and *turnover*. Hence, the null hypothesis, *H4d0*, is not rejected. *R&D personnel intensity* and *turnover* are statistically significant at the 1% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.74 in the likelihood of occurrence of process innovation.

- A 1 percent increase in the value of *turnover*, on average, leads to an increase of 7.04 percent in the likelihood of occurrence of process innovation.

According to the analysis of Turkish manufacturing industry with medium-low education intensity, there are many findings in terms of product innovation. These are:

- R&D expenditure variables except external-domestic are not statistically significant. Total, internal, external, and *external-foreign R&D expenditures* have positive effects on the likelihood of occurrence of product innovation. It means that more of these R&D expenditures increase the likelihood of occurrence of product innovation. The most effective expenditure type is *total R&D expenditure*.
- R&D intensity variables except external and external-foreign are not statistically significant at 10% level. External and external-foreign R&D intensities have positive effects on the likelihood of occurrence of product innovation. It means that more of these intensities increase the likelihood of occurrence of product innovation. The most effective intensity type is *external-foreign R&D intensity*.
- According to PDRE1 and PDRI1 models, *turnover* and *HHI* are statistically significant and have positive and negative effects respectively on the likelihood of occurrence of product innovation. It means that more *turnover* and more concentrated manufacturing industries with MLEI increase the likelihood of occurrence of product innovation.

According to the analysis of Turkish manufacturing industry with medium-low education intensity, there are many findings in terms of process innovation. These are:

- R&D expenditure variables except total and internal are not statistically significant at 10% level. Total and *internal R&D expenditures* are statistically significant and have positive effects on the likelihood of occurrence of process innovation. It means that more of these R&D expenditures increase the likelihood of occurrence of process innovation.

- R&D intensity variables are not statistically significant at 10% level.
- According to PCRE1 and PCRI1 models, *R&D personnel intensity* and *turnover* are statistically significant and have positive effects on the likelihood of occurrence of process innovation. It means that more *R&D personnel intensity* and more *turnover* increase the likelihood of occurrence of process. innovation.

Results of the analyses are also viewed by comparing product and process innovation in terms of Turkish manufacturing industry with medium-low education intensity. These are:

- The impact of *total* and *internal R&D expenditure* on the likelihood of occurrence of product innovation are greater than their impacts on the likelihood of occurrence of process innovation.
- *External* and *external-foreign R&D expenditure* and *external* and *external-foreign R&D intensity* affect only the likelihood of occurrence of product innovation positively.

5.2.4. Manufacturing Industries with Low Education Intensity (LEI)

Firms that are engaged in R&D in Turkish manufacturing industry with low education intensity are analyzed by with twenty models such as 10 product innovation models and 10 process innovation models, which are shown in Table 3 that is in Chapter 3 and in Appendix 7, 8, 9, and 10.

Regression results of PDRE1 and PCRE1 models include coefficient, p-value, and average marginal effect, which are shown in Table 226. These models analyze the effect of *total R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE1 model focuses on the relationship between product innovation and *total R&D expenditure*, which is shown in Table 226. Because the Wald test and all individual z-statistics (not shown here) are not statistically significant, the PDRE1

model is not shown here. Hence, the null hypothesis, $H1_0$, could not be tested for manufacturing industry with low education intensity.

The PCRE1 model focuses on the relationship between process innovation and *total R&D expenditure*, which is shown in Table 226. In this model, some independent variables such as *total R&D expenditure* and *turnover* are statistically significant at 5% level. Hence, the null hypothesis, $H3_0$, is rejected. The rest of the independent variables are not statistically significant at 10% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *total R&D expenditure*, on average, leads to an increase of 5.32 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.1 percent in the likelihood of occurrence of process innovation.

Table 226: Regression Results of PDRE1 and PCRE1 Models – LEI

Variable Name	PDRE1			PCRE1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntrdexpD</i>				0.1730	0.014 **	0.0532
<i>rdperint</i>				0.1027	0.879	0.0316
<i>IntoverD</i>				0.1659	0.044 **	0.0510
<i>HHI</i>				0.6471	0.179	0.1988
<i>phd_ma</i>				-0.0139	0.548	-0.0043
<i>ipicsec</i>				-0.0012	0.690	-0.0004

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE1: Wald $\chi^2(6) = 3.94$ Prob > $\chi^2 = 0.6852$

For PCRE1: Wald $\chi^2(6) = 19.56$ Prob > $\chi^2 = 0.0033$

Regression results of PDRE2 and PCRE2 models include coefficient, p-value, and average marginal effect, which are shown in Table 227. These models analyze the effect of *internal R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE2 model focuses on the relationship between product innovation and *internal R&D expenditure*, which is shown in Table 227. Because the Wald test and all individual z-statistics (not shown here) are not statistically significant, the PDRE2

model is not shown here. Hence, the null hypothesis, $H1a_0$, is could not be tested for manufacturing industry with low education intensity.

The PCRE2 model focuses on the relationship between process innovation and *internal R&D expenditure*, which is shown in Table 227. In this model, some independent variables such as *internal R&D expenditure* and *turnover* are statistically significant at 5% level. Hence, the null hypothesis, $H3a_0$, is rejected. The rest of the independent variables are not statistically significant at 10% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *internal R&D expenditure*, on average, leads to an increase of 5.52 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.02 percent in the likelihood of occurrence of process innovation.

Table 227: Regression Results of PDRE2 and PCRE2 Models – LEI

Variable Name	PDRE2			PCRE2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntintrdexpD</i>				0.1799	0.014 **	0.0552
<i>rdperint</i>				0.0713	0.916	0.0219
<i>IntoverD</i>				0.1638	0.048 **	0.0502
<i>HHI</i>				0.6544	0.175	0.2007
<i>phd_ma</i>				-0.0143	0.538	-0.0044
<i>ipicsec</i>				-0.0012	0.690	-0.0004

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE2: Wald $\chi^2(6) = 3.79$ Prob > $\chi^2 = 0.7050$

For PCRE2: Wald $\chi^2(6) = 19.52$ Prob > $\chi^2 = 0.0034$

Regression results of PDRE3 and PCRE3 models include coefficient, p-value, and average marginal effect, which are shown in Table 228. These models analyze the effect of *external R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE3 model focuses on the relationship between product innovation and *external R&D expenditure*, which is shown in Table 228. Because the Wald test and all individual z-statistics (not shown here) are not statistically significant, the PDRE3

model is not shown here. Hence, the null hypothesis, $H1b_0$, could not be tested for manufacturing industry with low education intensity.

Table 228: Regression Results of PDRE3 and PCRE3 Models – LEI

Variable Name	PDRE3			PCRE3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpD</i>				0.0170	0.508	0.0053
<i>rdperint</i>				1.0148	0.147	0.3184
<i>IntoverD</i>				0.2379	0.004 ***	0.0746
<i>HHI</i>				0.4558	0.323	0.1430
<i>phd_ma</i>				-0.0060	0.793	-0.0019
<i>ipicsec</i>				-0.0013	0.677	-0.0004

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE3: Wald $\chi^2(6) = 7.23$ Prob > $\chi^2 = 0.3002$

For PCRE3: Wald $\chi^2(6) = 14.44$ Prob > $\chi^2 = 0.0250$

The PCRE3 model focuses on the relationship between process innovation and *external R&D expenditure*, which is shown in Table 228. In this model, independent variables are not statistically significant at the 10% level, except *turnover*. *Turnover* is statistically significant at the 1% level. Hence, the null hypothesis, $H3b_0$, is not rejected. It means, *ceteris paribus*, that 1 percent increase in the value of *turnover*, on average, leads to an increase of 7.46 percent in the likelihood of occurrence of process innovation.

Regression results of PDRE4 and PCRE4 models include coefficient, p-value, and average marginal effect, which are shown in Table 229. These models analyze the effect of *external-domestic R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE4 model focuses on the relationship between product innovation and *external-domestic R&D expenditure*, which is shown in Table 229. Because the Wald test and all individual z-statistics (not shown here) are not statistically significant, the PDRE4 model is not shown here. Hence, the null hypothesis, $H1c_0$, could not be tested for manufacturing industry with low education intensity.

The PCRE4 model focuses on the relationship between process innovation and *external-domestic R&D expenditure*, which is shown in Table 229. In this model, independent variables are not statistically significant at the 10% level, except *turnover*.

Turnover is statistically significant at the 1% level. Hence, the null hypothesis, $H3c_0$, is not rejected. It means, *ceteris paribus*, that 1 percent increase in the value of *turnover*, on average, leads to an increase of 7.56 percent in the likelihood of occurrence of process innovation.

Table 229: Regression Results of PDRE4 and PCRE4 Models – LEI

Variable Name	PDRE4			PCRE4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpdomD</i>				0.0117	0.687	0.0037
<i>rdperint</i>				1.0559	0.111	0.3318
<i>IntoverD</i>				0.2405	0.004 ***	0.0756
<i>HHI</i>				0.4592	0.321	0.1443
<i>phd_ma</i>				-0.0055	0.815	-0.0017
<i>ipicsec</i>				-0.0013	0.666	-0.0004

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE4: Wald $\chi^2(6)=4.04$ Prob > $\chi^2=0.6709$

For PCRE4: Wald $\chi^2(6)=13.91$ Prob > $\chi^2=0.0307$

Regression results of PDRE5 and PCRE5 models include coefficient, p-value, and average marginal effect, which are shown in Table 230. These models analyze the effect of *external-foreign R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE5 model focuses on the relationship between product innovation and *external-foreign R&D expenditure*, which is shown in Table 230. In this model, independent variables are not statistically significant at the 10% level, except *external-foreign R&D expenditure* and the *number of highly educated R&D personnel*. *External-foreign R&D expenditure* is statistically significant at the 1% level. Hence, the null hypothesis, $H1d_0$, is rejected. The *number of highly educated R&D personnel* is statistically significant at the 5% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *external-foreign R&D expenditure*, on average, leads to an increase of 5.52 percent in the likelihood of occurrence of product innovation.

- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.01 in the likelihood of occurrence of product innovation.

The PCRE5 model focuses on the relationship between process innovation and *external-foreign R&D expenditure*, which is shown in Table 230. In this model, independent variables are not statistically significant at the 10% level, except *external-foreign R&D expenditure* and *turnover*. *External-foreign R&D expenditure* and *turnover* are statistically significant at the 1% level. Hence, the null hypothesis, $H3d_0$, is rejected. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *external-foreign R&D expenditure*, on average, leads to an increase of 3.61 percent in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 7.09 percent in the likelihood of occurrence of process innovation.

Table 230: Regression Results of PDRE5 and PCRE5 Models – LEI

Variable Name	PDRE5			PCRE5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpforD</i>	0.0706	0.000 ***	0.0255	0.1174	0.000 ***	0.0361
<i>rdperint</i>	0.0616	0.955	0.0222	1.0033	0.208	0.3084
<i>IntoverD</i>	0.0608	0.471	0.0219	0.2306	0.006 ***	0.0709
<i>HHI</i>	0.3753	0.426	0.1353	0.4655	0.322	0.1431
<i>phd_ma</i>	-0.0276	0.043 **	-0.0099	-0.0136	0.560	-0.0042
<i>ipicsec</i>	0.0004	0.872	0.0001	-0.0012	0.680	-0.0004

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE5: Wald $\chi^2(6) = 65.64$ Prob > $\chi^2 = 0.0000$

For PCRE5: Wald $\chi^2(6) = 50.44$ Prob > $\chi^2 = 0.0000$

Regression results of PDRI1 and PCRI1 models include coefficient, p-value, and average marginal effect, which are shown in Table 231. These models analyze the effect of *total R&D intensity* on the probability of product and process innovations, respectively.

The PDRI1 model focuses on the relationship between product innovation and *total R&D intensity*, which is shown in Table 231. Because the Wald test and 5 of 6 individual z-statistics (not shown here) are not statistically significant, the PDRI1

model is not shown here. Hence, the null hypothesis, $H2_0$, could not be tested for manufacturing industry with low education intensity.

The PCRI1 model focuses on the relationship between process innovation and *total R&D intensity*, which is shown in Table 231. In this model, independent variables are not statistically significant at 10% level, except *total R&D intensity* and *turnover*. *Total R&D intensity* and *turnover* are statistically significant at 5% and 1% levels, respectively. Hence, the null hypothesis, $H4_0$, is not rejected. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *total R&D intensity*, on average, leads to an increase of 0.52 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 7.76 percent in the likelihood of occurrence of process innovation.

Table 231: Regression Results of PDRI1 and PCRI1 Models – LEI

Variable Name	PDRI1			PCRI1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>totrdint</i>				1.6634	0.038 **	0.5211
<i>rdperint</i>				0.2040	0.800	0.0639
<i>IntoverD</i>				0.2476	0.002 ***	0.0776
<i>HHI</i>				0.5376	0.246	0.1684
<i>phd_ma</i>				-0.0035	0.883	-0.0011
<i>ipicsec</i>				-0.0013	0.644	-0.0004

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI1: Wald $\chi^2(6)=8.00$ Prob > $\chi^2=0.2382$

For PCRI1: Wald $\chi^2(6)=16.71$ Prob > $\chi^2=0.0104$

Regression results of PDRI2 and PCRI2 models include coefficient, p-value, and average marginal effect, which are shown in Table 232. These models analyze the effect of *internal R&D intensity* on the probability of product and process innovations, respectively.

The PDRI2 model focuses on the relationship between product innovation and *internal R&D intensity*, which is shown in Table 232. Because the Wald test and 5 of 6 individual z-statistics (not shown here) are not statistically significant, the PDRI2 model is not shown here. Hence, the null hypothesis, $H2a_0$, could not be tested for manufacturing industry with low education intensity.

The PCRI2 model focuses on the relationship between process innovation and *internal R&D intensity*, which is shown in Table 232. In this model, independent variables are not statistically significant at the 10% level, except *internal R&D intensity* and *turnover*. *Internal R&D intensity* and *turnover* are statistically significant at the 10% and 1% levels, respectively. Hence, the null hypothesis, $H4a_0$, is not rejected. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *internal R&D intensity*, on average, leads to an increase of 0.45 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 7.71 percent in the likelihood of occurrence of process innovation.

Table 232: Regression Results of PDRI2 and PCRI2 Models – LEI

Variable Name	PDRI2			PCRI2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>intrdint</i>				1.4414	0.067 *	0.4521
<i>rdperint</i>				0.3143	0.703	0.0986
<i>IntoverD</i>				0.2458	0.002 ***	0.0771
<i>HHI</i>				0.5255	0.256	0.1648
<i>phd_ma</i>				-0.0032	0.893	-0.0010
<i>ipicsec</i>				-0.0014	0.635	-0.0004

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI2: Wald $\chi^2(6) = 6.64$ Prob > $\chi^2 = 0.3556$

For PCRI2: Wald $\chi^2(6) = 16.04$ Prob > $\chi^2 = 0.0136$

Regression results of PDRI3 and PCRI3 models include coefficient, p-value, and average marginal effect, which are shown in Table 233. These models analyze the effect of *external R&D intensity* on the probability of product and process innovations, respectively.

The PDRI3 model focuses on the relationship between product innovation and *external R&D intensity*, which is shown in Table 233. Because the Wald test and all individual z-statistics (not shown here) are not statistically significant, the PDRI3 model is not shown here. Hence, the null hypothesis, $H2b_0$, could not be tested for manufacturing industry with low education intensity.

The PCRI3 model focuses on the relationship between process innovation and *external R&D intensity*, which is shown in Table 233. In this model, independent

variables are not statistically significant at the 10% level, except *turnover*. *Turnover* is statistically significant at the 1% level. Hence, the null hypothesis, $H4b_0$, is not rejected. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 7.68 percent in the likelihood of occurrence of process innovation.

Table 233: Regression Results of PDRI3 and PCRI3 Models – LEI

Variable Name	PDRI3			PCRI3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extrdint</i>				112.91	0.477	35.260
<i>rdperint</i>				0.8740	0.237	0.2729
<i>IntoverD</i>				0.2459	0.002 ***	0.0768
<i>HHI</i>				0.4772	0.301	0.1490
<i>phd_ma</i>				-0.0059	0.792	-0.0018
<i>ipicsec</i>				-0.0013	0.661	-0.0004

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI3: Wald $\chi^2(6)=2.10$ Prob > $\chi^2=0.9099$

For PCRI3: Wald $\chi^2(6)=14.12$ Prob > $\chi^2=0.0283$

Regression results of PDRI4 and PCRI4 models include coefficient, p-value, and average marginal effect, which are shown in Table 234. These models analyze the effect of *external-domestic R&D intensity* on the probability of product and process innovations, respectively.

The PDRI4 model focuses on the relationship between product innovation and *external-domestic R&D intensity*, which is shown in Table 234. Because the Wald test and all individual z-statistics (not shown here) are not statistically significant, the PDRI4 model is not shown here. Hence, the null hypothesis, $H2c_0$, could not be tested for manufacturing industry with low education intensity.

The PCRI4 model focuses on the relationship between process innovation and *external-domestic R&D intensity*, which is shown in Table 234. In this model, independent variables are not statistically significant at the 10% level, except *external-domestic R&D intensity* and *turnover*. *External-domestic R&D intensity* and *turnover* are statistically significant at the 1% level. Hence, the null hypothesis, $H4c_0$, is rejected. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external-domestic R&D intensity*, on average, leads to an increase of 3.72 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 7.79 percent in the likelihood of occurrence of process innovation.

Table 234: Regression Results of PDRI4 and PCRI4 Models – LEI

Variable Name	PDRI4			PCRI4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extdomrdint</i>				11.836	0.000 ***	3.7147
<i>rdperint</i>				1.0061	0.118	0.3158
<i>IntoverD</i>				0.2481	0.002 ***	0.0779
<i>HHI</i>				0.4865	0.290	0.1527
<i>phd_ma</i>				-0.0051	0.829	-0.0016
<i>ipicsec</i>				-0.0013	0.666	-0.0004

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI4: Wald chi2(6)=2.22 Prob > chi2=0.8984

For PCRI4: Wald chi2(6)=81.55 Prob > chi2=0.0000

Regression results of PDRI5 and PCRI5 models include coefficient, p-value, and average marginal effect, which are shown in Table 235. These models analyze the effect of *external-foreign R&D intensity* on the probability of product and process innovations, respectively.

The PDRI5 model focuses on the relationship between product innovation and *external-foreign R&D intensity*, which is shown in Table 235. In this model, independent variables are not statistically significant at the 10% level, except *external-foreign R&D intensity*. *External-foreign R&D intensity* is statistically significant at 1% level. Hence, the null hypothesis, $H2d_0$, is rejected.

The PCRI5 model focuses on the relationship between process innovation and *external-foreign R&D intensity*, which is shown in Table 235. In this model, independent variables are not statistically significant at the 10% level, except *external-foreign R&D intensity* and *turnover*. *External-foreign R&D intensity* and *turnover* are statistically significant at the 1% level. Hence, the null hypothesis, $H4d_0$, is rejected. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external-foreign R&D intensity*, on average, leads to an increase of 2889.66 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 7.42 percent in the likelihood of occurrence of process innovation.

Table 235: Regression Results of PDRI5 and PCRI5 Models – LEI

Variable Name	PDRI5			PCRI5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extfrgrdint</i>	7335.9	0.000 ***	2594.52	9410.53	0.000 ***	2889.66
<i>rdperint</i>	-0.2418	0.843	-0.0855	1.2815	0.143	0.3935
<i>IntoverD</i>	0.0566	0.511	0.0200	0.2416	0.004 ***	0.0742
<i>HHI</i>	0.5073	0.288	0.1794	0.5411	0.248	0.1662
<i>phd_ma</i>	-0.0218	0.104	-0.0077	-0.0145	0.335	-0.0045
<i>ipicsec</i>	0.0005	0.840	0.0002	-0.0012	0.664	-0.0004

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI5: Wald chi2(6)=61.59 Prob > chi2=0.0000

For PCRI5: Wald chi2(6)=49.13 Prob > chi2=0.0000

According to the analysis of Turkish manufacturing industry with low education intensity, there are many findings in terms of product innovation. These are:

- PDRE models except PDRE5 are not statistically significant according to the Wald test. In other words, *external-foreign R&D expenditure* is statistically significant and has positive effect on the likelihood of occurrence of product innovation. It means that more *external-foreign R&D expenditure* increases the likelihood of occurrence of product innovation.
- PDRI models except PDRI5 are not statistically significant according to the Wald test. In other words, *external-foreign R&D intensity* is statistically significant and has positive effect on the likelihood of occurrence of product innovation. It means that more *external-foreign R&D intensity* increases the likelihood of occurrence of product innovation.
- PDRE1 and PDRI1 models are not statistically significant according to the Wald test.

According to the analysis of Turkish manufacturing industry with low education intensity, there are many findings in terms of process innovation. These are:

- R&D expenditure variables except external and external-domestic are statistically significant and they have positive effects on the likelihood of occurrence of process innovation. It means that more total, internal, and *external-foreign R&D expenditures* increase the likelihood of occurrence of process innovation. The most effective expenditure type is *internal R&D intensity*.
- R&D intensity variables except external are statistically significant and they have positive effects on the likelihood of occurrence of process innovation. It means that more of these R&D intensities increase the likelihood of occurrence of process innovation. The most effective intensity type is *external-foreign R&D intensity*.
- According to PCRE1 and PCRI1 models, *turnover* is statistically significant and has positive effect on the likelihood of occurrence of process innovation. It means that more *turnover* increases the likelihood of occurrence of process innovation.

Results of the analyses are also viewed by comparing product and process innovation in terms of Turkish manufacturing industry with low education intensity. These are:

- *Total* and *internal R&D expenditures* affect only the likelihood of occurrence of process innovation positively.
- The impact of *external-foreign R&D expenditure* on the likelihood of occurrence of process innovation is greater than its impact on the likelihood of occurrence of product innovation.
- *Total, internal, and external-domestic R&D intensity* affect only the likelihood of occurrence of process innovation positively.

- The impact of *external-foreign R&D intensity* on the likelihood of occurrence of process innovation is greater than its impact on the likelihood of occurrence of product innovation.

Results and findings from the analysis of Turkish manufacturing industry by education intensity classification are presented here. The differences in terms of the effects of R&D expenditures and R&D intensities on the likelihood of occurrence of product and process innovations are investigated with the twenty models for each class. The results of the analyses in terms of product and process innovation are summarized in Appendix 15 and 16, which presented many statistics about R&D expenditure and R&D intensity variables such as their positive or negative effects, their significance level, and their average marginal effect. Results of the analyses are also viewed by comparing product and process innovation according to technology intensity classification.

The effects of the rest of independent variables such as *turnover*, *HHI*, the *number of highly educated R&D personnel*, and *industrial production index by manufacturing industry* are explained generally, especially by focusing on the PDRE1 and PDRI1 (product innovation models), and PCRE1 and PCRI1 (process innovation models). Because these models include two main and inclusive independent variables such as *total R&D expenditure* and *total R&D intensity*. To explain the results, the effects of R&D expenditure is interpreted in terms of percentages, and the effects of R&D intensity is interpreted in terms of units.

In the next, the analysis of Turkish manufacturing industry by firm size is presented.

5.3. Turkish Manufacturing Industry Analysis – Firm Size (FS)

The analysis of all Turkish manufacturing industry by firm size classification include all manufacturing industries, except manufacture of tobacco products. This classification includes small size ($n < 50$), medium size ($n < 250$), and large size ($n > 250$). Firms are classified by their size with respect to the number of employees (European Commission, 2020).

The analysis by firm size classification is significant to understand the effect of firms according to their sizes. In other words, differences among firms by size must be revealed to improve more efficient R&D policies. Nutter (1956) emphasized that firm size is one of the essential stimulants of economic progress. According to Töngür and Taymaz (2019), the determining and designing of sectoral and employment policies by firm size is significant instead of general policies.

5.3.1. Turkish Manufacturing Industry with Small Size Firm

Firms that are engaged in R&D in Turkish manufacturing industry with small size firm are analyzed by with twenty models such as 10 product innovation models and 10 process innovation models, which are shown in Table 3 that is in Chapter 3 and in Appendix 7, 8, 9, and 10.

Regression results of PDRE1 and PCRE1 models include coefficient, p-value, and average marginal effect, which are shown in Table 236. These models analyze the effect of *total R&D expenditure* on the probability of product and process innovations, respectively.

Table 236: Regression Results of PDRE1 and PCRE1 Models – Small

Variable Name	PDRE1			PCRE1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntrdexpD</i>				0.0320	0.304	0.0109
<i>rdperint</i>				0.5386	0.039 **	0.1826
<i>IntoverD</i>				0.1511	0.000 ***	0.0512
<i>HHI</i>				0.5056	0.343	0.1714
<i>phd_ma</i>				0.0053	0.244	0.0018
<i>ipicsec</i>				0.0022	0.036 **	0.0007

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE1: Wald chi2(6)=9.45 Prob > chi2=0.1499

For PCRE1: Wald chi2(6)=38.73 Prob > chi2=0.0000

The PDRE1 model focuses on the relationship between product innovation and *total R&D expenditure*, which is shown in Table 236. Because the Wald test and 5 of 6 individual z-statistics (not shown here) are not statistically significant, the PDRE1 model is not shown here. Hence, the null hypothesis, $H1_0$, is could not be tested for manufacturing industry with small size firm.

The PCRE1 model focuses on the relationship between process innovation and *total R&D expenditure*, which is shown in Table 236. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity*, *turnover*, and *industrial production index by manufacturing industry*. Hence, the null hypothesis, H_{30} , is not rejected. *R&D personnel intensity*, *turnover*, and *industrial production index by manufacturing industry* are statistically significant at 5%, 1%, and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.18 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.12 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.07 percent in the likelihood of occurrence of process innovation.

Regression results of PDRE2 and PCRE2 models include coefficient, p-value, and average marginal effect, which are shown in Table 237. These models analyze the effect of *internal R&D expenditure* on the probability of product and process innovations, respectively.

Table 237: Regression Results of PDRE2 and PCRE2 Models – Small

Variable Name	PDRE2			PCRE2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntintrdexpD</i>				0.0318	0.312	0.0108
<i>rdperint</i>				0.5398	0.038 **	0.1830
<i>IntoverD</i>				0.1512	0.000 ***	0.0513
<i>HHI</i>				0.5076	0.342	0.1721
<i>phd_ma</i>				0.0054	0.242	0.0018
<i>ipicsec</i>				0.0022	0.037 **	0.0007

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE2: Wald $\chi^2(6)=9.25$ Prob > $\chi^2=0.1600$

For PCRE2: Wald $\chi^2(6)=38.70$ Prob > $\chi^2=0.0000$

The PDRE2 model focuses on the relationship between product innovation and *internal R&D expenditure*, which is shown in Table 237. Because the Wald test and 5 of 6 individual z-statistics (not shown here) are not statistically significant, the PDRE2

model is not shown here. Hence, the null hypothesis, $H1a_0$, is could not be tested for manufacturing industry with small size firm.

The PCRE2 model focuses on the relationship between process innovation and *internal R&D expenditure*, which is shown in Table 237. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity*, *turnover*, and *industrial production index by manufacturing industry*. Hence, the null hypothesis, $H3a_0$, is not rejected. *R&D personnel intensity*, *turnover*, and *industrial production index by manufacturing industry* are statistically significant at 5%, 1%, and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.18 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.13 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.07 percent in the likelihood of occurrence of process innovation.

Regression results of PDRE3 and PCRE3 models include coefficient, p-value, and average marginal effect, which are shown in Table 238. These models analyze the effect of *external R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE3 model focuses on the relationship between product innovation and *external R&D expenditure*, which is shown in Table 238. Because the Wald test and 4 of 6 individual z-statistics (not shown here) are not statistically significant, the PDRE3 model is not shown here. Hence, the null hypothesis, $H1b_0$, is could not be tested for manufacturing industry with small size firm.

The PCRE3 model focuses on the relationship between process innovation and *external R&D expenditure*, which is shown in Table 238. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity*, *turnover*, and *industrial production index by manufacturing industry*. Hence, the null

hypothesis, $H3b_0$, is not rejected. *R&D personnel intensity*, *turnover*, and *industrial production index by manufacturing industry* are statistically significant at 5%, 1%, and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.22 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.67 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.08 percent in the likelihood of occurrence of process innovation.

Table 238: Regression Results of PDRE3 and PCRE3 Models – Small

Variable Name	PDRE3			PCRE3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpD</i>				0.0077	0.275	0.0026
<i>rdperint</i>				0.6360	0.017 **	0.2158
<i>IntoverD</i>				0.1671	0.000 ***	0.0567
<i>HHI</i>				0.4839	0.367	0.1642
<i>phd_ma</i>				0.0071	0.184	0.0024
<i>ipicsec</i>				0.0023	0.024 **	0.0008

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE3: Wald $\chi^2(6) = 9.31$ Prob > $\chi^2 = 0.1570$

For PCRE3: Wald $\chi^2(6) = 40.61$ Prob > $\chi^2 = 0.0000$

Regression results of PDRE4 and PCRE4 models include coefficient, p-value, and average marginal effect, which are shown in Table 239. These models analyze the effect of *external-domestic R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE4 model focuses on the relationship between product innovation and *external-domestic R&D expenditure*, which is shown in Table 239. Because the Wald test and 5 of 6 individual z-statistics (not shown here) are not statistically significant, the PDRE4 model is not shown here. Hence, the null hypothesis, $H1c_0$, is could not be tested for manufacturing industry with small size firm.

The PCRE4 model focuses on the relationship between process innovation and *external-domestic R&D expenditure*, which is shown in Table 239. In this model,

independent variables are not statistically significant at 10% level, except *R&D personnel intensity*, *turnover*, and *industrial production index by manufacturing industry*. Hence, the null hypothesis, $H3c_0$, is not rejected. *R&D personnel intensity*, *turnover*, and *industrial production index by manufacturing industry* are statistically significant at 5%, 1%, and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.22 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.7 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.08 percent in the likelihood of occurrence of process innovation.

Table 239: Regression Results of PDRE4 and PCRE4 Models – Small

Variable Name	PDRE4			PCRE4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpdomD</i>				0.0048	0.543	0.0016
<i>rdperint</i>				0.6431	0.015 **	0.2183
<i>IntoverD</i>				0.1680	0.000 ***	0.0570
<i>HHI</i>				0.4871	0.365	0.1654
<i>phd_ma</i>				0.0072	0.175	0.0024
<i>ipicsec</i>				0.0023	0.025 **	0.0008

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE4: Wald $\chi^2(6)=7.55$ Prob > $\chi^2=0.2732$

For PCRE4: Wald $\chi^2(6)=39.21$ Prob > $\chi^2=0.0000$

Regression results of PDRE5 and PCRE5 models include coefficient, p-value, and average marginal effect, which are shown in Table 240. These models analyze the effect of *external-foreign R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE5 model focuses on the relationship between product innovation and *external-foreign R&D expenditure*, which is shown in Table 240. Because the Wald test and 5 of 6 individual z-statistics (not shown here) are not statistically significant,

the PDRE5 model is not shown here. Hence, the null hypothesis, $H1d_0$, is could not be tested for manufacturing industry with small size firm.

Table 240: Regression Results of PDRE5 and PCRE5 Models – Small

Variable Name	PDRE5			PCRE5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpforD</i>				0.0179	0.008 ***	0.0061
<i>rdperint</i>				0.6368	0.016 **	0.2159
<i>IntoverD</i>				0.1663	0.000 ***	0.0564
<i>HHI</i>				0.4973	0.357	0.1686
<i>phd_ma</i>				0.0069	0.207	0.0023
<i>ipicsec</i>				0.0024	0.022 **	0.0008

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE5: Wald $\chi^2(6)=6.22$ Prob > $\chi^2=0.3995$

For PCRE5: Wald $\chi^2(6)=47.53$ Prob > $\chi^2=0.0000$

The PCRE5 model focuses on the relationship between process innovation and *external-foreign R&D expenditure*, which is shown in Table 240. In this model, independent variables are not statistically significant at 10% level, except *external-foreign R&D expenditure*, *R&D personnel intensity*, *turnover*, and *industrial production index by manufacturing industry*. *External-foreign R&D expenditure* is statistically significant at the 1% level. Hence, the null hypothesis, $H3d_0$, is rejected. *R&D personnel intensity*, *turnover*, and *industrial production index by manufacturing industry* are statistically significant at 5%, 1%, and 5% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *external-foreign R&D expenditure*, on average, leads to an increase of 0.61 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.22 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.64 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.08 percent in the likelihood of occurrence of process innovation.

Regression results of PDRI1 and PCRI1 models include coefficient, p-value, and average marginal effect, which are shown in Table 241. These models analyze the effect of *total R&D intensity* on the probability of product and process innovations, respectively.

The PDRI1 model focuses on the relationship between product innovation and *total R&D intensity*, which is shown in Table 241. Because the Wald test and 4 of 6 individual z-statistics (not shown here) are not statistically significant, the PDRI1 model is not shown here. Hence, the null hypothesis, H_{20} , could not be tested for manufacturing industry with small size firm.

Table 241: Regression Results of PDRI1 and PCRI1 Models – Small

Variable Name	PDRI1			PCRI1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>totrdint</i>				0.0778	0.623	0.0264
<i>rdperint</i>				0.6180	0.029 **	0.2098
<i>lntoverD</i>				0.1699	0.000 ***	0.0577
<i>HHI</i>				0.5000	0.354	0.1698
<i>phd_ma</i>				0.0072	0.159	0.0024
<i>ipicsec</i>				0.0023	0.026 **	0.0008

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI1: Wald $\chi^2(6)=8.78$ Prob > $\chi^2=0.1866$

For PCRI1: Wald $\chi^2(6)=37.37$ Prob > $\chi^2=0.0000$

The PCRI1 model focuses on the relationship between process innovation and *total R&D intensity*, which is shown in Table 241. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity*, *turnover*, and *industrial production index by manufacturing industry*. *R&D personnel intensity*, *turnover*, and *industrial production index by manufacturing industry* are statistically significant at 5%, 1%, and 5% levels, respectively. Hence, the null hypothesis, H_{40} , is not rejected. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.21 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.77 percent in the likelihood of occurrence of process innovation.

- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.08 percent in the likelihood of occurrence of process innovation.

Regression results of PDRI2 and PCRI2 models include coefficient, p-value, and average marginal effect, which are shown in Table 242. These models analyze the effect of *internal R&D intensity* on the probability of product and process innovations, respectively.

The PDRI2 model focuses on the relationship between product innovation and *internal R&D intensity*, which is shown in Table 242. Because the Wald test and 4 of 6 individual z-statistics (not shown here) are not statistically significant, the PDRI2 model is not shown here. Hence, the null hypothesis, $H2a_0$, could not be tested for manufacturing industry with small size firm.

Table 242: Regression Results of PDRI2 and PCRI2 Models – Small

Variable Name	PDRI2			PCRI2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>intrdint</i>				-0.0433	0.834	-0.0147
<i>rdperint</i>				0.6593	0.025 **	0.2239
<i>IntoverD</i>				0.1686	0.000 ***	0.0572
<i>HHI</i>				0.4920	0.361	0.1671
<i>phd_ma</i>				0.0075	0.141	0.0026
<i>ipicsec</i>				0.0023	0.026 **	0.0008

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI2: Wald $\chi^2(6)=7.31$ Prob > $\chi^2=0.2929$

For PCRI2: Wald $\chi^2(6)=37.45$ Prob > $\chi^2=0.0000$

The PCRI2 model focuses on the relationship between process innovation and *internal R&D intensity*, which is shown in Table 242. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity*, *turnover*, and *industrial production index by manufacturing industry*. *R&D personnel intensity*, *turnover*, and *industrial production index by manufacturing industry* are statistically significant at 5%, 1%, and 5% levels, respectively. Hence, the null hypothesis, $H4a_0$, is not rejected. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.22 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.72 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.08 percent in the likelihood of occurrence of process innovation.

Regression results of PDRI3 and PCRI3 models include coefficient, p-value, and average marginal effect, which are shown in Table 243. These models analyze the effect of *external R&D intensity* on the probability of product and process innovations, respectively.

Table 243: Regression Results of PDRI3 and PCRI3 Models – Small

Variable Name	PDRI3			PCRI3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extrdint</i>	0.4322	0.007 ***	0.1524	0.4881	0.000 ***	0.1656
<i>rdperint</i>	0.1007	0.609	0.0355	0.6214	0.017 **	0.2108
<i>IntoverD</i>	0.0567	0.092 *	0.0200	0.1701	0.000 ***	0.0577
<i>HHI</i>	0.6756	0.315	0.2383	0.4890	0.362	0.1659
<i>phd_ma</i>	0.0039	0.417	0.0014	0.0074	0.152	0.0025
<i>ipicsec</i>	0.0018	0.079 *	0.0007	0.0024	0.023 **	0.0008

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI3: Wald chi2(6)=12.02 Prob > chi2=0.0614

For PCRI3: Wald chi2(6)=48.18 Prob > chi2=0.0000

The PDRI3 model focuses on the relationship between product innovation and *external R&D intensity*, which is shown in Table 243. In this model, independent variables are not statistically significant at 10% level, except *external R&D intensity*, *turnover*, and *industrial production index by manufacturing industry*. *External R&D intensity* is statistically significant at 1% level. Hence, the null hypothesis, $H2b_0$, is rejected. The *turnover* and *industrial production index by manufacturing industry* are statistically significant at the 10% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external R&D intensity*, on average, leads to an increase of 0.15 in the likelihood of occurrence of product innovation.

- A 1 percent increase in the value of *turnover*, on average, leads to an increase of 2 percent in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.07 percent in the likelihood of occurrence of product innovation.

The PCRI3 model focuses on the relationship between process innovation and *external R&D intensity*, which is shown in Table 243. In this model, independent variables are not statistically significant at 10% level, except *external R&D intensity*, *R&D personnel intensity*, *turnover*, and *industrial production index by manufacturing industry*. *External R&D intensity* is statistically significant at 1% level. Hence, the null hypothesis, $H4b_0$, is rejected. *R&D personnel intensity*, *turnover*, and *industrial production index by manufacturing industry* are statistically significant at 5%, 1%, and 5% levels, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external R&D intensity*, on average, leads to an increase of 0.17 in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.21 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.77 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.08 percent in the likelihood of occurrence of process innovation.

Regression results of PDRI4 and PCRI4 models include coefficient, p-value, and average marginal effect, which are shown in Table 244. These models analyze the effect of *external-domestic R&D intensity* on the probability of product and process innovations, respectively.

The PDRI4 model focuses on the relationship between product innovation and *external-domestic R&D intensity*, which is shown in Table 244. In this model, independent variables are not statistically significant at 10% level, except *external-*

domestic R&D intensity, *turnover*, and *industrial production index by manufacturing industry*. *External-domestic R&D intensity* is statistically significant at 5% level. Hence, the null hypothesis, $H2c_0$, is rejected. The *turnover* and *industrial production index by manufacturing industry* are statistically significant at the 10% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external R&D intensity*, on average, leads to an increase of 0.14 in the likelihood of occurrence of product innovation.
- A 1 percent increase in the value of *turnover*, on average, leads to an increase of 2 percent in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.07 percent in the likelihood of occurrence of product innovation.

The PCRI4 model focuses on the relationship between process innovation and *external-domestic R&D intensity*, which is shown in Table 244. In this model, independent variables are statistically significant, except *HHI* and the *number of highly educated R&D personnel*. *external-domestic R&D intensity* is statistically significant at 5% level. Hence, the null hypothesis, $H4c_0$, is rejected. *R&D personnel intensity*, *turnover*, and *industrial production index by manufacturing industry* are statistically significant at 5%, 1%, and 5% levels, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external-domestic R&D intensity*, on average, leads to an increase of 0.16 in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.21 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.77 percent in the likelihood of occurrence of process innovation.

- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.08 percent in the likelihood of occurrence of process innovation.

Table 244: Regression Results of PDRI4 and PCRI4 Models – Small

Variable Name	PDRI4			PCRI4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extdomrdint</i>	0.4069	0.011 **	0.1435	0.4591	0.000 ***	0.1558
<i>rdperint</i>	0.1023	0.603	0.0361	0.6234	0.017 **	0.2115
<i>lntoverD</i>	0.0567	0.092 *	0.0200	0.1701	0.000 ***	0.0577
<i>HHI</i>	0.6753	0.315	0.2382	0.4889	0.363	0.1659
<i>phd_ma</i>	0.0039	0.415	0.0014	0.0074	0.152	0.0025
<i>ipicsec</i>	0.0018	0.079 *	0.0007	0.0024	0.023 **	0.0008

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI4: Wald chi2(6)=11.16 Prob > chi2=0.0835

For PCRI4: Wald chi2(6)=46.02 Prob > chi2=0.0000

Regression results of PDRI5 and PCRI5 models include coefficient, p-value, and average marginal effect, which are shown in Table 245. These models analyze the effect of *external-foreign R&D intensity* on the probability of product and process innovations, respectively.

The PDRI5 model focuses on the relationship between product innovation and *external-foreign R&D intensity*, which is shown in Table 245. In this model, independent variables are not statistically significant, except *external-foreign R&D intensity* and *industrial production index by manufacturing industry*. *External-foreign R&D intensity* is statistically significant at 1% level. Hence, the null hypothesis, H_{2d0} , is rejected. *Industrial production index by manufacturing industry* is statistically significant at 10% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external-foreign R&D intensity*, on average, leads to an increase of 14.92 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.07 percent in the likelihood of occurrence of product innovation.

Table 245: Regression Results of PDRI5 and PCRI5 Models – Small

Variable Name	PDRI5			PCRI5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extfrgrdint</i>	42.485	0.000 ***	14.918	52.821	0.000 ***	17.856
<i>rdperint</i>	0.1041	0.602	0.0365	0.6368	0.017 **	0.2153
<i>IntoverD</i>	0.0540	0.109	0.0190	0.1683	0.000 ***	0.0569
<i>HHI</i>	0.6705	0.320	0.2354	0.4891	0.362	0.1654
<i>phd_ma</i>	0.0047	0.322	0.0017	0.0078	0.097 *	0.0027
<i>ipicsec</i>	0.0020	0.057 *	0.0007	0.0025	0.016 **	0.0008

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI5: Wald chi2(6)=26.17 Prob > chi2=0.0002

For PCRI5: Wald chi2(6)=60.67 Prob > chi2=0.0000

The PCRI5 model focuses on the relationship between process innovation and *external-foreign R&D intensity*, which is shown in Table 245. In this model, independent variables are statistically significant, except *HHI*. *External-foreign R&D intensity* is statistically significant at 1% level. Hence, the null hypothesis, *H4d0*, is rejected. *R&D personnel intensity*, *turnover*, the *number of highly educated R&D personnel*, and *industrial production index by manufacturing industry* are statistically significant at 5%, 1%, 10%, and 5% levels, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external-foreign R&D intensity*, on average, leads to an increase of 17.9 in the likelihood of occurrence of process innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.22 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 5.69 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.003 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.08 percent in the likelihood of occurrence of process innovation.

According to the analysis of Turkish manufacturing industry with small size firm, there are many findings in terms of product innovation. These are:

- R&D expenditure models are not statistically significant according to the Wald test.
- PDRI1 and PDRI2 models are not statistically significant according to the Wald test. R&D intensity variables such as external, external-domestic, and external-foreign are statistically significant and have positive effects on the likelihood of occurrence of product innovation. It means that more of these R&D intensities increase the likelihood of occurrence of product innovation.
- PDRE1 and PDRI1 models are not statistically significant according to the Wald test.

According to the analysis of Turkish manufacturing industry with small size firm, there are many findings in terms of process innovation. These are:

- R&D expenditure variables except external-foreign are not statistically significant at 10% level. *External-foreign R&D expenditure* is statistically significant and has positive effect on the likelihood of occurrence of process innovation. It means that more *external-foreign R&D expenditure* increases the likelihood of occurrence of process innovation.
- R&D intensity variables except total and internal are statistically significant and have positive effects on the likelihood of occurrence of process innovation. It means that more of these R&D intensities increase the likelihood of occurrence of process innovation. The most effective one is *external-foreign R&D intensity*.
- According to PCRE1 and PCRI1 models, *R&D personnel intensity*, *turnover*, and *industrial production index by manufacturing industry* are statistically significant and have positive effect on the likelihood of occurrence of process innovation. It means that more *R&D personnel intensity*, more *turnover*, and more *industrial production index by*

manufacturing industry increase the likelihood of occurrence of process innovation.

Results of the analyses are also viewed by comparing product and process innovation in terms of Turkish manufacturing industry with small size firm. These are:

- *External-foreign R&D expenditure* affects only the likelihood of occurrence of process innovation positively.
- The impact of *external, external-domestic, and external-foreign R&D intensity* on the likelihood of occurrence of process innovation are greater than their impacts on the likelihood of occurrence of product innovation.

5.3.2. Turkish Manufacturing Industry with Medium Size Firm

Firms that are engaged in R&D in Turkish manufacturing industry with medium size firm are analyzed by with twenty models such as 10 product innovation models and 10 process innovation models, which are shown in Table 3 that is in Chapter 3 and in Appendix 7, 8, 9, and 10.

Regression results of PDRE1 and PCRE1 models include coefficient, p-value, and average marginal effect, which are shown in Table 246. These models analyze the effect of *total R&D expenditure* on the probability of product and process innovations, respectively.

Table 246: Regression Results of PDRE1 and PCRE1 Models – Medium

Variable Name	PDRE1			PCRE1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntrdexpD</i>	0.1024	0.002 ***	0.0361	0.0576	0.094 *	0.0202
<i>rdperint</i>	0.5306	0.116	0.1873	-0.1690	0.599	-0.0593
<i>IntoverD</i>	-0.0238	0.557	-0.0084	-0.0369	0.446	-0.0129
<i>HHI</i>	1.1532	0.191	0.4070	1.1037	0.209	0.3870
<i>phd_ma</i>	0.0044	0.415	0.0015	0.0272	0.035 **	0.0096
<i>ipicsec</i>	0.0020	0.119	0.0007	0.0018	0.287	0.0006

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE1: Wald chi2(6)=25.11 Prob > chi2=0.0003

For PCRE1: Wald chi2(6)=15.18 Prob > chi2=0.0189

The PDRE1 model focuses on the relationship between product innovation and *total R&D expenditure*, which is shown in Table 246. In this model, independent

variables are not statistically significant at 10% level, except *total R&D expenditure*. *Total R&D expenditure* is statistically significant at 1% level. Hence, the null hypothesis, $H1_0$, is rejected. It means, *ceteris paribus*, that 1 percent increase in the value of *total R&D expenditure*, on average, leads to an increase of 3.61 percent in the likelihood of occurrence of product innovation.

The PCRE1 model focuses on the relationship between process innovation and *total R&D expenditure*, which is shown in Table 246. In this model, independent variables are not statistically significant at 10% level, except *total R&D expenditure* and the *number of highly educated R&D personnel*. *Total R&D expenditure* is statistically significant at 1% level. Hence, the null hypothesis, $H3_0$, is rejected. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *total R&D expenditure*, on average, leads to an increase of 2.02 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.01 in the likelihood of occurrence of process innovation.

Regression results of PDRE2 and PCRE2 models include coefficient, p-value, and average marginal effect, which are shown in Table 247. These models analyze the effect of *internal R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE2 model focuses on the relationship between product innovation and *internal R&D expenditure*, which is shown in Table 247. In this model, independent variables are not statistically significant at 10% level, except *internal R&D expenditure*. *Internal R&D expenditure* is statistically significant at 1% level. Hence, the null hypothesis, $H1a_0$, is rejected. It means, *ceteris paribus*, that 1 percent increase in the value of *total R&D expenditure*, on average, leads to an increase of 3.53 percent in the likelihood of occurrence of product innovation.

The PCRE2 model focuses on the relationship between process innovation and *internal R&D expenditure*, which is shown in Table 247. In this model, independent variables are not statistically significant at 10% level, except the *number of highly educated R&D personnel*. Hence, the null hypothesis, $H3a_0$, is not rejected. It means, *ceteris paribus*, that a unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.01 in the likelihood of occurrence of process innovation.

Table 247: Regression Results of PDRE2 and PCRE2 Models – Medium

Variable Name	PDRE2			PCRE2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntintrdexpD</i>	0.1001	0.002 ***	0.0353	0.0562	0.103	0.0197
<i>rdperint</i>	0.5252	0.121	0.1854	-0.1690	0.600	-0.0593
<i>IntoverD</i>	-0.0236	0.562	-0.0083	-0.0367	0.449	-0.0129
<i>HHI</i>	1.1779	0.177	0.4158	1.1180	0.200	0.3921
<i>phd_ma</i>	0.0044	0.410	0.0016	0.0273	0.035 **	0.0096
<i>ipicsec</i>	0.0020	0.119	0.0007	0.0018	0.287	0.0006

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE2: Wald $\chi^2(6)=24.53$ Prob > $\chi^2=0.0004$

For PCRE2: Wald $\chi^2(6)=15.15$ Prob > $\chi^2=0.0191$

Regression results of PDRE3 and PCRE3 models include coefficient, p-value, and average marginal effect, which are shown in Table 248. These models analyze the effect of *external R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE3 model focuses on the relationship between product innovation and *external R&D expenditure*, which is shown in Table 248. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity* and *industrial production index by manufacturing industry*. Hence, the null hypothesis, $H1b_0$, is not rejected. *R&D personnel intensity* and *industrial production index by manufacturing industry* are statistically significant at 1% and 10% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.38 in the likelihood of occurrence of product innovation.

- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.08 percent in the likelihood of occurrence of product innovation.

Table 248: Regression Results of PDRE3 and PCRE3 Models – Medium

Variable Name	PDRE3			PCRE3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpD</i>	0.0069	0.408	0.0025	0.0086	0.364	0.0030
<i>rdperint</i>	1.0667	0.007 ***	0.3799	0.0333	0.916	0.0117
<i>IntoverD</i>	0.0251	0.508	0.0089	-0.0132	0.778	-0.0047
<i>HHI</i>	1.1634	0.227	0.4143	1.0738	0.238	0.3779
<i>phd_ma</i>	0.0095	0.339	0.0034	0.0323	0.009 ***	0.0114
<i>ipicsec</i>	0.0021	0.091 *	0.0008	0.0020	0.233	0.0007

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE3: Wald chi2(6)=17.10 Prob > chi2=0.0089

For PCRE3: Wald chi2(6)=14.41 Prob > chi2=0.0254

The PCRE3 model focuses on the relationship between process innovation and *external R&D expenditure*, which is shown in Table 248. In this model, independent variables are not statistically significant at 10% level, except the *number of highly educated R&D personnel*. Hence, the null hypothesis, $H3b_0$, is not rejected. It means, *ceteris paribus*, that a unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.011 in the likelihood of occurrence of process innovation.

Regression results of PDRE4 and PCRE4 models include coefficient, p-value, and average marginal effect, which are shown in Table 249. These models analyze the effect of *external-domestic R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE4 model focuses on the relationship between product innovation and *external-domestic R&D expenditure*, which is shown in Table 249. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity* and *industrial production index by manufacturing industry*. Hence, the null hypothesis, $H1c_0$, is not rejected. *R&D personnel intensity* and *industrial production index by manufacturing industry* are statistically significant at 1% and 10% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.38 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.08 percent in the likelihood of occurrence of product innovation.

The PCRE4 model focuses on the relationship between process innovation and *external-domestic R&D expenditure*, which is shown in Table 249. In this model, independent variables are not statistically significant at 10% level, except the *number of highly educated R&D personnel*. Hence, the null hypothesis, $H3c_0$, is not rejected. It means, *ceteris paribus*, that a unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.012 in the likelihood of occurrence of process innovation.

Table 249: Regression Results of PDRE4 and PCRE4 Models – Medium

Variable Name	PDRE4			PCRE4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpdomD</i>	0.0095	0.273	0.0034	0.0054	0.478	0.0019
<i>rdperint</i>	1.0690	0.007 ***	0.3806	0.0444	0.888	0.0156
<i>IntoverD</i>	0.0259	0.496	0.0092	-0.0129	0.783	-0.0045
<i>HHI</i>	1.1525	0.235	0.4103	1.0897	0.227	0.3836
<i>phd_ma</i>	0.0093	0.345	0.0033	0.0327	0.008 ***	0.0115
<i>ipicsec</i>	0.0021	0.090 *	0.0008	0.0020	0.241	0.0007

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRE4: Wald $\chi^2(6)=17.92$ Prob > $\chi^2=0.0064$

For PCRE4: Wald $\chi^2(6)=13.11$ Prob > $\chi^2=0.0413$

Regression results of PDRE5 and PCRE5 models include coefficient, p-value, and average marginal effect, which are shown in Table 250. These models analyze the effect of *external-foreign R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE5 model focuses on the relationship between product innovation and *external-foreign R&D expenditure*, which is shown in Table 250. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity* and *industrial production index by manufacturing industry*. Hence, the null hypothesis, $H1d_0$, is not rejected. *R&D personnel intensity* and *industrial*

production index by manufacturing industry are statistically significant at 1% and 10% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.38 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.08 percent in the likelihood of occurrence of product innovation.

Table 250: Regression Results of PDRE5 and PCRE5 Models – Medium

Variable Name	PDRE5			PCRE5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpforD</i>	0.0008	0.932	0.0003	0.0292	0.026 **	0.0103
<i>rdperint</i>	1.0706	0.007 ***	0.3813	0.0007	0.998	0.0003
<i>IntoverD</i>	0.0247	0.513	0.0088	-0.0180	0.700	-0.0063
<i>HHI</i>	1.1966	0.209	0.4262	1.0678	0.236	0.3752
<i>phd_ma</i>	0.0101	0.317	0.0036	0.0315	0.011 **	0.0111
<i>ipicsec</i>	0.0021	0.096 *	0.0008	0.0020	0.238	0.0007

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE5: Wald chi2(6)=15.22 Prob > chi2=0.0186

For PCRE5: Wald chi2(6)=22.02 Prob > chi2=0.0012

The PCRE5 model focuses on the relationship between process innovation and *external-foreign R&D expenditure*, which is shown in Table 250. In this model, independent variables are not statistically significant at 10% level, except *external-foreign R&D expenditure* and the *number of highly educated R&D personnel*. *External-foreign R&D expenditure* and the *number of highly educated R&D personnel* are statistically significant at 5% level. Hence, the null hypothesis, $H3d_0$, is rejected. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *external-foreign R&D expenditure*, on average, leads to an increase of 1.03 percent in the likelihood of occurrence of process innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.011 in the likelihood of occurrence of process innovation.

Regression results of PDRI1 and PCRI1 models include coefficient, p-value, and average marginal effect, which are shown in Table 251. These models analyze the effect of *total R&D intensity* on the probability of product and process innovations, respectively.

The PDRI1 model focuses on the relationship between product innovation and *total R&D intensity*, which is shown in Table 251. In this model, independent variables are not statistically significant at 10% level, except *total R&D intensity*, *R&D personnel intensity*, and *industrial production index by manufacturing industry*. *Total R&D intensity* is statistically significant at 1% level. Hence, the null hypothesis, H_{20} , is rejected. *R&D personnel intensity* and *industrial production index by manufacturing industry* are statistically significant at 10% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *total R&D intensity*, on average, leads to an increase of 0.63 in the likelihood of occurrence of product innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.32 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.08 percent in the likelihood of occurrence of product innovation.

The PCRI1 model focuses on the relationship between process innovation and *total R&D intensity*, which is shown in Table 251. In this model, independent variables are not statistically significant at 10% level, except *total R&D intensity* and the *number of highly educated R&D personnel*. *Total R&D intensity* is statistically significant at 10% level. Hence, the null hypothesis, H_{40} , is rejected. The *number of highly educated R&D personnel* is statistically significant at 1% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *total R&D intensity*, on average, leads to an increase of 0.15 in the likelihood of occurrence of process innovation.

- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.012 in the likelihood of occurrence of process innovation.

Table 251: Regression Results of PDRI1 and PCRI1 Models – Medium

Variable Name	PDRI1			PCRI1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>totrdint</i>	1.7855	0.003 ***	0.6303	0.4391	0.064 *	0.1543
<i>rdperint</i>	0.9107	0.099 *	0.3215	-0.3527	0.455	-0.1239
<i>IntoverD</i>	0.0552	0.186	0.0195	-0.0019	0.970	-0.0007
<i>HHI</i>	1.2085	0.205	0.4266	1.1664	0.209	0.4099
<i>phd_ma</i>	0.0063	0.409	0.0022	0.0328	0.009 ***	0.0115
<i>ipicsec</i>	0.0022	0.086 *	0.0008	0.0021	0.229	0.0007

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI1: Wald chi2(6)=16.70 Prob > chi2=0.0104

For PCRI1: Wald chi2(6)=17.00 Prob > chi2=0.0093

Regression results of PDRI2 and PCRI2 models include coefficient, p-value, and average marginal effect, which are shown in Table 252. These models analyze the effect of *internal R&D intensity* on the probability of product and process innovations, respectively.

The PDRI2 model focuses on the relationship between product innovation and *internal R&D intensity*, which is shown in Table 252. In this model, independent variables are not statistically significant at 10% level, except *internal R&D intensity* and *industrial production index by manufacturing industry*. *Internal R&D intensity* is statistically significant at 1% level. Hence, the null hypothesis, H_{2a0} , is rejected. *Industrial production index by manufacturing industry* is statistically significant at 10% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *internal R&D intensity*, on average, leads to an increase of 0.58 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.08 percent in the likelihood of occurrence of product innovation.

The PCRI2 model focuses on the relationship between process innovation and *internal R&D intensity*, which is shown in Table 252. In this model, independent

variables are not statistically significant at 10% level, except *internal R&D intensity* and the *number of highly educated R&D personnel*. *Internal R&D intensity* is statistically significant at 10% level. Hence, the null hypothesis, $H4a_0$, is rejected. The *number of highly educated R&D personnel* is statistically significant at 1% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *internal R&D intensity*, on average, leads to an increase of 0.13 in the likelihood of occurrence of process innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.012 in the likelihood of occurrence of process innovation.

Table 252: Regression Results of PDRI2 and PCRI2 Models – Medium

Variable Name	PDRI2			PCRI2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>intrdint</i>	1.6501	0.006 ***	0.5830	0.3683	0.097 *	0.1295
<i>rdperint</i>	0.9075	0.111	0.3207	-0.3255	0.498	-0.1144
<i>IntoverD</i>	0.0485	0.243	0.0172	-0.0043	0.932	-0.0015
<i>HHI</i>	1.2051	0.205	0.4258	1.1640	0.209	0.4091
<i>phd_ma</i>	0.0067	0.404	0.0024	0.0329	0.008 ***	0.0116
<i>ipicsec</i>	0.0021	0.092 *	0.0008	0.0021	0.230	0.0007

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI2: Wald $\chi^2(6) = 15.40$ Prob > $\chi^2 = 0.0173$

For PCRI2: Wald $\chi^2(6) = 17.34$ Prob > $\chi^2 = 0.0081$

Regression results of PDRI3 and PCRI3 models include coefficient, p-value, and average marginal effect, which are shown in Table 253. These models analyze the effect of *external R&D intensity* on the probability of product and process innovations, respectively.

The PDRI3 model focuses on the relationship between product innovation and *external R&D intensity*, which is shown in Table 253. In this model, independent variables are not statistically significant at 10% level, except *external R&D intensity*, *R&D personnel intensity*, and *industrial production index by manufacturing industry*. *External R&D intensity* is statistically significant at 1% level. Hence, the null hypothesis, $H2b_0$, is rejected. *R&D personnel intensity* and *industrial production index*

by manufacturing industry are statistically significant at 1% and 10% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external R&D intensity*, on average, leads to an increase of 1.01 in the likelihood of occurrence of product innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.39 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.08 percent in the likelihood of occurrence of product innovation.

Table 253: Regression Results of PDRI3 and PCRI3 Models – Medium

Variable Name	PDRI3			PCRI3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extrdint</i>	2.8370	0.006 ***	1.0095	2.3059	0.002 ***	0.8110
<i>rdperint</i>	1.0828	0.006 ***	0.3853	0.0779	0.805	0.0274
<i>IntoverD</i>	0.0323	0.402	0.0115	-0.0075	0.875	-0.0027
<i>HHI</i>	1.2081	0.207	0.4299	1.1190	0.211	0.3936
<i>phd_ma</i>	0.0099	0.321	0.0035	0.0330	0.007 ***	0.0116
<i>ipicsec</i>	0.0022	0.086 *	0.0008	0.0020	0.237	0.0007

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI3: Wald chi2(6)=18.39 Prob > chi2=0.0053

For PCRI3: Wald chi2(6)=17.94 Prob > chi2=0.0064

The PCRI3 model focuses on the relationship between process innovation and *external R&D intensity*, which is shown in Table 253. In this model, independent variables are not statistically significant at 10% level, except *external R&D intensity* and the *number of highly educated R&D personnel*. *External R&D intensity* is statistically significant at 1% level. Hence, the null hypothesis, $H4b_0$, is rejected. The *number of highly educated R&D personnel* is statistically significant at 1% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external R&D intensity*, on average, leads to an increase of 0.81 in the likelihood of occurrence of process innovation.

- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.012 in the likelihood of occurrence of process innovation.

Regression results of PDRI4 and PCRI4 models include coefficient, p-value, and average marginal effect, which are shown in Table 254. These models analyze the effect of *external-domestic R&D intensity* on the probability of product and process innovations, respectively.

Table 254: Regression Results of PDRI4 and PCRI4 Models – Medium

Variable Name	PDRI4			PCRI4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extdomrdint</i>	2.8398	0.013 **	1.0105	2.2463	0.007 ***	0.7901
<i>rdperint</i>	1.0822	0.006 ***	0.3851	0.0766	0.809	0.0269
<i>IntoverD</i>	0.0322	0.403	0.0115	-0.0077	0.872	-0.0027
<i>HHI</i>	1.2085	0.207	0.4300	1.1193	0.211	0.3937
<i>phd_ma</i>	0.0100	0.319	0.0036	0.0330	0.007 ***	0.0116
<i>ipicsec</i>	0.0022	0.086 *	0.0008	0.0020	0.238	0.0007

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI4: Wald chi2(6)=17.75 Prob > chi2=0.0069

For PCRI4: Wald chi2(6)=16.09 Prob > chi2=0.0133

The PDRI4 model focuses on the relationship between product innovation and *external-domestic R&D intensity*, which is shown in Table 254. In this model, independent variables are not statistically significant at 10% level, except *external-domestic R&D intensity*, *R&D personnel intensity*, and *industrial production index by manufacturing industry*. *External-domestic R&D intensity* is statistically significant at 10% level. Hence, the null hypothesis, $H2c_0$, is rejected. *R&D personnel intensity* and *industrial production index by manufacturing industry* are statistically significant at 1% and 10% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external R&D intensity*, on average, leads to an increase of 1.01 in the likelihood of occurrence of product innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.39 in the likelihood of occurrence of product innovation.

- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.08 percent in the likelihood of occurrence of product innovation.

The PCRI4 model focuses on the relationship between process innovation and *external-domestic R&D intensity*, which is shown in Table 254. In this model, independent variables are not statistically significant at 10% level, except *external-domestic R&D intensity* and the *number of highly educated R&D personnel*. *External-domestic R&D intensity* is statistically significant at 1% level. Hence, the null hypothesis, $H4c_0$, is rejected. The *number of highly educated R&D personnel* is statistically significant at 1% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external-domestic R&D intensity*, on average, leads to an increase of 0.79 in the likelihood of occurrence of process innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.012 in the likelihood of occurrence of process innovation.

Regression results of PDRI5 and PCRI5 models include coefficient, p-value, and average marginal effect, which are shown in Table 255. These models analyze the effect of *external-foreign R&D intensity* on the probability of product and process innovations, respectively.

The PDRI5 model focuses on the relationship between product innovation and *external-foreign R&D intensity*, which is shown in Table 255. In this model, independent variables are not statistically significant at 10% level, except *external-foreign R&D intensity*, *R&D personnel intensity*, and *industrial production index by manufacturing industry*. *External-foreign R&D intensity* is statistically significant at 1% level. Hence, the null hypothesis, $H2d_0$, is rejected. *R&D personnel intensity* and *industrial production index by manufacturing industry* are statistically significant at 1% and 10% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external-foreign R&D intensity*, on average, leads to an increase of 68.95 in the likelihood of occurrence of product innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.38 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.08 percent in the likelihood of occurrence of product innovation.

Table 255: Regression Results of PDRI5 and PCRI5 Models – Medium

Variable Name	PDRI5			PCRI5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extfrgrdint</i>	194.52	0.002 ***	68.948	477.10	0.059 *	166.75
<i>rdperint</i>	1.0816	0.007 ***	0.3834	0.0020	0.995	0.0007
<i>lntoverD</i>	0.0258	0.499	0.0091	-0.0156	0.740	-0.0055
<i>HHI</i>	1.1981	0.206	0.4247	1.1802	0.194	0.4125
<i>phd_ma</i>	0.0089	0.356	0.0031	0.0310	0.014 **	0.0108
<i>ipicsec</i>	0.0022	0.086 *	0.0008	0.0021	0.217	0.0007

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI5: Wald chi2(6)=24.27 Prob > chi2=0.0005

For PCRI5: Wald chi2(6)=18.05 Prob > chi2=0.0061

The PCRI5 model focuses on the relationship between process innovation and *external-foreign R&D intensity*, which is shown in Table 255. In this model, independent variables are not statistically significant at 10% level, except *external-foreign R&D intensity* and the *number of highly educated R&D personnel*. *External-foreign R&D intensity* is statistically significant at 10% level. Hence, the null hypothesis, $H4d_0$, is rejected. The *number of highly educated R&D personnel* is statistically significant at 5% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *external-foreign R&D intensity*, on average, leads to an increase of 166.75 in the likelihood of occurrence of process innovation.

- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.011 in the likelihood of occurrence of process innovation.

According to the analysis of Turkish manufacturing industry with medium size firm, there are many findings in terms of product innovation. These are:

- R&D expenditure variables except total and internal are not statistically significant at 10% level. Total and *internal R&D expenditures* have positive effects on the likelihood of occurrence of product innovation. It means that more total and *internal R&D expenditures* increase the likelihood of occurrence of product innovation. The most effective expenditure type is *total R&D expenditure*.
- All R&D intensity variables are statistically significant and have positive effects on the likelihood of occurrence of product innovation. It means that more of these intensities increase the likelihood of occurrence of product innovation. The most effective intensity type is *external-foreign R&D intensity*.
- According to PDRE1 model, other independent variables are not statistically significant at 10% level. According to PDRI1 model, *R&D personnel intensity* and *industrial production index by manufacturing industry* are statistically significant and have positive effect on the likelihood of occurrence of product innovation. It means that more *R&D personnel intensity* and more *industrial production index by manufacturing industry* increase the likelihood of occurrence of product innovation.

According to the analysis of Turkish manufacturing industry with medium size firm, there are many findings in terms of process innovation. These are:

- R&D expenditure variables except total and external-foreign are not statistically significant at 10% level. *Total* and *external-foreign R&D expenditures* have positive effects on the likelihood of occurrence of process innovation. It means that more total and *external-foreign R&D*

expenditures increase the likelihood of occurrence of process innovation. The most effective expenditure type is *total R&D expenditure*.

- All R&D intensity variables are statistically significant and have positive effects on the likelihood of occurrence of process innovation. It means that more of these intensities increase the likelihood of occurrence of process innovation. The most effective one is *external-foreign R&D intensity*.
- According to PCRE1 and PCRI1 models, the *number of highly educated R&D personnel* is statistically significant and has positive effect on the likelihood of occurrence of process innovation. It means that more highly educated R&D personnel increases the likelihood of occurrence of process innovation.

Results of the analyses are also viewed by comparing product and process innovation in terms of Turkish manufacturing industry with medium size firm. These are:

- The impact of *total R&D expenditure* on the likelihood of occurrence of product innovation are greater than its impact on the likelihood of occurrence of process innovation.
- *Internal R&D expenditure* affects only the likelihood of occurrence of product innovation positively.
- *External-foreign R&D expenditure* affects only the likelihood of occurrence of process innovation positively.
- The impact of total, internal, external, and external-domestic R&D intensities on the likelihood of occurrence of product innovation are greater than their impacts on the likelihood of occurrence of process innovation.
- The impact of *external-foreign R&D intensity* on the likelihood of occurrence of process innovation is greater than its impact on the likelihood of occurrence of product innovation.

5.3.3. Turkish Manufacturing Industry with Large Size Firm

Firms that are engaged in R&D in Turkish manufacturing industry with large size firm are analyzed by with twenty models such as 10 product innovation models and 10 process innovation models, which are shown in Table 3 that is in Chapter 3 and in Appendix 7, 8, 9, and 10.

Regression results of PDRE1 and PCRE1 models include coefficient, p-value, and average marginal effect, which are shown in Table 256. These models analyze the effect of *total R&D expenditure* on the probability of product and process innovations, respectively.

Table 256: Regression Results of PDRE1 and PCRE1 Models – Large

Variable Name	PDRE1			PCRE1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>lntrdexpD</i>	0.1491	0.000 ***	0.0456	0.1121	0.000 ***	0.0308
<i>rdperint</i>	0.0426	0.838	0.0130	0.4007	0.141	0.1100
<i>lntoverD</i>	0.0452	0.286	0.0138	0.1577	0.000 ***	0.0433
<i>HHI</i>	-1.1764	0.084 *	-0.3599	1.9586	0.023 **	0.5377
<i>phd_ma</i>	0.0018	0.317	0.0005	-0.0004	0.401	-0.0001
<i>ipicsec</i>	-0.0002	0.874	-0.00005	0.0020	0.067 *	0.0006

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE1: Wald chi2(6)=63.24 Prob > chi2=0.0000

For PCRE1: Wald chi2(6)=71.33 Prob > chi2=0.0000

The PDRE1 model focuses on the relationship between product innovation and *total R&D expenditure*, which is shown in Table 256. In this model, independent variables are not statistically significant at 10% level, except *total R&D expenditure* and *HHI*. *Total R&D expenditure* is statistically significant at 1% level. Hence, the null hypothesis, $H1_0$, is rejected. *HHI* is statistically significant at 10% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *total R&D expenditure*, on average, leads to an increase of 4.56 percent in the likelihood of occurrence of product innovation.
- An increase in *HHI* of 0.01, on average, leads to a decrease of 0.36 in the likelihood of occurrence of product innovation.

The PCRE1 model focuses on the relationship between process innovation and *total R&D expenditure*, which is shown in Table 256. In this model, independent variables are statistically significant at 10% level, except *R&D personnel intensity* and the *number of highly educated R&D personnel*. *Total R&D expenditure* and *turnover* are statistically significant at 1% level. Hence, the null hypothesis, $H3_0$, is rejected. *HHI* and *industrial production index by manufacturing industry* are statistically significant at 5% and 10% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *total R&D expenditure*, on average, leads to an increase of 3.08 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.33 percent in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 0.54 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.06 percent in the likelihood of occurrence of process innovation.

Regression results of PDRE2 and PCRE2 models include coefficient, p-value, and average marginal effect, which are shown in Table 257. These models analyze the effect of *internal R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE2 model focuses on the relationship between product innovation and *internal R&D expenditure*, which is shown in Table 257. In this model, independent variables are not statistically significant at 10% level, except *internal R&D expenditure* and *HHI*. *Internal R&D expenditure* is statistically significant at 1% level. Hence, the null hypothesis, $H1a_0$, is rejected. *HHI* is statistically significant at 10% level. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *total R&D expenditure*, on average, leads to an increase of 4.57 percent in the likelihood of occurrence of product innovation.
- An increase in *HHI* of 0.01, on average, leads to a decrease of 0.36 in the likelihood of occurrence of product innovation.

Table 257: Regression Results of PDRE2 and PCRE2 Models – Large

Variable Name	PDRE2			PCRE2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntintrdexpD</i>	0.1493	0.000 ***	0.0457	0.1137	0.000 ***	0.0312
<i>rdperint</i>	0.0362	0.861	0.0111	0.3853	0.154	0.1058
<i>IntoverD</i>	0.0459	0.277	0.0140	0.1574	0.000 ***	0.0432
<i>HHI</i>	-1.1821	0.082 *	-0.3618	1.9570	0.023 **	0.5373
<i>phd_ma</i>	0.0017	0.316	0.0005	-0.0004	0.384	-0.0001
<i>ipicsec</i>	-0.0002	0.863	-0.0001	0.0020	0.069 *	0.0006

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE2: Wald chi2(6)=62.50 Prob > chi2=0.0000

For PCRE2: Wald chi2(6)=71.27 Prob > chi2=0.0000

The PCRE2 model focuses on the relationship between process innovation and *internal R&D expenditure*, which is shown in Table 257. In this model, independent variables are statistically significant at 10% level, except *R&D personnel intensity* and the *number of highly educated R&D personnel*. *Total R&D expenditure* and *turnover* are statistically significant at 1% level. Hence, the null hypothesis, H_{3a0} , is rejected. *HHI* and *industrial production index by manufacturing industry* are statistically significant at 5% and 10% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *total R&D expenditure*, on average, leads to an increase of 3.12 percent in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 4.32 percent in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 0.54 in the likelihood of occurrence of process innovation.

- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.06 percent in the likelihood of occurrence of process innovation.

Regression results of PDRE3 and PCRE3 models include coefficient, p-value, and average marginal effect, which are shown in Table 258. These models analyze the effect of *external R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE3 model focuses on the relationship between product innovation and *external R&D expenditure*, which is shown in Table 258. In this model, independent variables are not statistically significant at 10% level, except *external R&D expenditure*, *R&D personnel intensity*, and *turnover*. *External R&D expenditure* is statistically significant at 10% level. Hence, the null hypothesis, $H1b_0$, is rejected. *R&D personnel intensity* and *turnover* are statistically significant at 5% and 1% levels, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *external R&D expenditure*, on average, leads to an increase of 0.35 percent in the likelihood of occurrence of product innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.37 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 3.85 percent in the likelihood of occurrence of product innovation.

The PCRE3 model focuses on the relationship between process innovation and *external R&D expenditure*, which is shown in Table 258. In this model, independent variables are statistically significant at 10% level, except *external R&D expenditure* and the *number of highly educated R&D personnel*. Hence, the null hypothesis, $H3b_0$, is not rejected. *R&D personnel intensity* and *turnover* are statistically significant at 1% level. *HHI* and *industrial production index by manufacturing industry* are statistically significant at 5% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.44 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 6.55 percent in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 0.68 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.07 percent in the likelihood of occurrence of process innovation.

Table 258: Regression Results of PDRE3 and PCRE3 Models – Large

Variable Name	PDRE3			PCRE3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpD</i>	0.0112	0.066 *	0.0035	-0.0057	0.439	-0.0016
<i>rdperint</i>	1.1679	0.027 **	0.3667	1.5743	0.007 ***	0.4404
<i>IntoverD</i>	0.1227	0.003 ***	0.0385	0.2341	0.000 ***	0.0655
<i>HHI</i>	-1.1049	0.136	-0.3469	2.4339	0.029 **	0.6809
<i>phd_ma</i>	0.0062	0.116	0.0020	0.0007	0.721	0.0002
<i>ipicsec</i>	0.0005	0.572	0.0002	0.0024	0.021 **	0.0007

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE3: Wald chi2(6)=32.04 Prob > chi2=0.0000

For PCRE3: Wald chi2(6)=50.80 Prob > chi2=0.0000

Regression results of PDRE4 and PCRE4 models include coefficient, p-value, and average marginal effect, which are shown in Table 259. These models analyze the effect of *external-domestic R&D expenditure* on the probability of product and process innovations, respectively.

The PDRE4 model focuses on the relationship between product innovation and *external-domestic R&D expenditure*, which is shown in Table 259. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity* and *turnover*. Hence, the null hypothesis, $H1c_0$, is not rejected. *R&D personnel intensity* and *turnover* are statistically significant at 5% and 1% levels, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.37 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 3.89 percent in the likelihood of occurrence of product innovation.

Table 259: Regression Results of PDRE4 and PCRE4 Models – Large

Variable Name	PDRE4			PCRE4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpdomD</i>	0.0072	0.251	0.0023	-0.0102	0.180	-0.0028
<i>rdperint</i>	1.1800	0.026 **	0.3711	1.5969	0.007 ***	0.4467
<i>IntoverD</i>	0.1236	0.003 ***	0.0389	0.2359	0.000 ***	0.0660
<i>HHI</i>	-1.0918	0.138	-0.3433	2.4418	0.028 **	0.6830
<i>phd_ma</i>	0.0064	0.105	0.0020	0.0007	0.719	0.0002
<i>ipicsec</i>	0.0005	0.615	0.0002	0.0024	0.021 **	0.0007

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE4: Wald chi2(6)=29.06 Prob > chi2=0.0001

For PCRE4: Wald chi2(6)=51.08 Prob > chi2=0.0000

The PCRE4 model focuses on the relationship between process innovation and *external-domestic R&D expenditure*, which is shown in Table 259. In this model, independent variables are statistically significant at 10% level, except *external-domestic R&D expenditure* and the *number of highly educated R&D personnel*. Hence, the null hypothesis, $H3c_0$, is not rejected. *R&D personnel intensity* and *turnover* are statistically significant at 1% level. *HHI* and *industrial production index by manufacturing industry* are statistically significant at 5% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.45 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 6.6 percent in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 0.68 in the likelihood of occurrence of process innovation.

- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.07 percent in the likelihood of occurrence of process innovation.

Regression results of PDRE5 and PCRE5 models include coefficient, p-value, and average marginal effect, which are shown in Table 260. These models analyze the effect of *external-foreign R&D expenditure* on the probability of product and process innovations, respectively.

Table 260: Regression Results of PDRE5 and PCRE5 Models – Large

Variable Name	PDRE5			PCRE5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>IntextrdexpforD</i>	0.0235	0.060 *	0.0073	0.0227	0.140	0.0063
<i>rdperint</i>	1.1930	0.026 **	0.3735	1.5104	0.008 ***	0.4204
<i>IntoverD</i>	0.1230	0.004 ***	0.0385	0.2290	0.000 ***	0.0637
<i>HHI</i>	-1.0942	0.136	-0.3425	2.3696	0.027 **	0.6596
<i>phd_ma</i>	0.0065	0.105	0.0020	0.0003	0.818	0.0001
<i>ipicsec</i>	0.0005	0.576	0.0002	0.0026	0.013 **	0.0007

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRE5: Wald chi2(6)=31.93 Prob > chi2=0.0000

For PCRE5: Wald chi2(6)=56.14 Prob > chi2=0.0000

The PDRE5 model focuses on the relationship between product innovation and *external-foreign R&D expenditure*, which is shown in Table 260. In this model, independent variables are not statistically significant at 10% level, except *external-foreign R&D expenditure*, *R&D personnel intensity*, and *turnover*. *External-foreign R&D expenditure* is statistically significant at 10% level. Hence, the null hypothesis, $H1d_0$, is rejected. *R&D personnel intensity* and *turnover* are statistically significant at 5% and 1% levels, respectively. There are many results of this model, *ceteris paribus*, such as:

- 1 percent increase in the value of *external-foreign R&D expenditure*, on average, leads to an increase of 0.73 percent in the likelihood of occurrence of product innovation.
- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.37 in the likelihood of occurrence of product innovation.

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 3.85 percent in the likelihood of occurrence of product innovation.

The PCRE5 model focuses on the relationship between process innovation and *external-foreign R&D expenditure*, which is shown in Table 260. In this model, independent variables are statistically significant at 10% level, except *external-foreign R&D expenditure* and the *number of highly educated R&D personnel*. Hence, the null hypothesis, $H3d_0$, is not rejected. *R&D personnel intensity* and *turnover* are statistically significant at 1% level. *HHI* and *industrial production index by manufacturing industry* are statistically significant at 5% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.4 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 6.37 percent in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 0.66 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.07 percent in the likelihood of occurrence of process innovation.

Regression results of PDRI1 and PCRI1 models include coefficient, p-value, and average marginal effect, which are shown in Table 261. These models analyze the effect of *total R&D intensity* on the probability of product and process innovations, respectively.

The PDRI1 model focuses on the relationship between product innovation and *total R&D intensity*, which is shown in Table 261. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity*, *turnover*, and the *number of highly educated R&D personnel*. Hence, the null hypothesis, $H2_0$, is not rejected. *R&D personnel intensity*, *turnover*, and the *number of highly educated*

R&D personnel are statistically significant at 10%, 1%, and 10% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.37 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 3.98 percent in the likelihood of occurrence of product innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.002 in the likelihood of occurrence of product innovation.

Table 261: Regression Results of PDRI1 and PCRI1 Models – Large

Variable Name	PDRI1			PCRI1		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>totrdint</i>	0.0253	0.628	0.0080	0.0626	0.264	0.0175
<i>rdperint</i>	1.1750	0.062 *	0.3699	1.4253	0.043 **	0.3983
<i>IntoverD</i>	0.1266	0.003 ***	0.0398	0.2330	0.000 ***	0.0651
<i>HHI</i>	-1.0697	0.142	-0.3367	2.4280	0.028 **	0.6784
<i>phd_ma</i>	0.0066	0.096 *	0.0021	0.0007	0.708	0.0002
<i>ipicsec</i>	0.0004	0.648	0.0001	0.0025	0.018 **	0.0007

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI1: Wald chi2(6)=27.21 Prob > chi2=0.0001

For PCRI1: Wald chi2(6)=51.74 Prob > chi2=0.0000

The PCRI1 model focuses on the relationship between process innovation and *total R&D intensity*, which is shown in Table 261. In this model, independent variables are statistically significant at 10% level, except *total R&D intensity* and the *number of highly educated R&D personnel*. Hence, the null hypothesis, H_{40} , is not rejected. *R&D personnel intensity*, *HHI*, and *industrial production index by manufacturing industry* are statistically significant at 5% level. *Turnover* is statistically significant at 1% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.4 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 6.51 percent in the likelihood of occurrence of process innovation.

- An increase in *HHI* of 0.01, on average, leads to an increase of 0.68 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.07 percent in the likelihood of occurrence of process innovation.

Regression results of PDRI2 and PCRI2 models include coefficient, p-value, and average marginal effect, which are shown in Table 262. These models analyze the effect of *internal R&D intensity* on the probability of product and process innovations, respectively.

Table 262: Regression Results of PDRI2 and PCRI2 Models – Large

Variable Name	PDRI2			PCRI2		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>intrdint</i>	0.0277	0.622	0.0087	0.0587	0.328	0.0164
<i>rdperint</i>	1.1753	0.062 *	0.3700	1.4360	0.042 **	0.4013
<i>IntoverD</i>	0.1266	0.003 ***	0.0399	0.2329	0.000 ***	0.0651
<i>HHI</i>	-1.0698	0.142	-0.3367	2.4261	0.028 **	0.6779
<i>phd_ma</i>	0.0066	0.096 *	0.0021	0.0007	0.710	0.0002
<i>ipicsec</i>	0.0004	0.648	0.0001	0.0025	0.018 **	0.0007

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI2: Wald chi2(6)=27.13 Prob > chi2=0.0001

For PCRI2: Wald chi2(6)=51.47 Prob > chi2=0.0000

The PDRI2 model focuses on the relationship between product innovation and *internal R&D intensity*, which is shown in Table 262. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity*, *turnover*, and the *number of highly educated R&D personnel*. Hence, the null hypothesis, $H2a_0$, is not rejected. *R&D personnel intensity*, *turnover*, and the *number of highly educated R&D personnel* are statistically significant at 10%, 1%, and 10% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.37 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 3.99 percent in the likelihood of occurrence of product innovation.

- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.002 in the likelihood of occurrence of product innovation.

The PCRI2 model focuses on the relationship between process innovation and *internal R&D intensity*, which is shown in Table 262. In this model, independent variables are statistically significant at 10% level, except *internal R&D intensity* and the *number of highly educated R&D personnel*. Hence, the null hypothesis, $H4a_0$, is not rejected. *R&D personnel intensity*, *HHI*, and *industrial production index by manufacturing industry* are statistically significant at 5% level. *Turnover* is statistically significant at 1% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.4 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 6.51 percent in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 0.68 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.07 percent in the likelihood of occurrence of process innovation.

Regression results of PDRI3 and PCRI3 models include coefficient, p-value, and average marginal effect, which are shown in Table 263. These models analyze the effect of *external R&D intensity* on the probability of product and process innovations, respectively.

The PDRI3 model focuses on the relationship between product innovation and *external R&D intensity*, which is shown in Table 263. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity*, *turnover*, and the *number of highly educated R&D personnel*. Hence, the null hypothesis, $H2b_0$, is not rejected. *R&D personnel intensity*, *turnover*, and the *number*

of highly educated R&D personnel are statistically significant at 5%, 1%, and 10% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.37 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 3.97 percent in the likelihood of occurrence of product innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.002 in the likelihood of occurrence of product innovation.

Table 263: Regression Results of PDRI3 and PCRI3 Models – Large

Variable Name	PDRI3			PCRI3		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extrdint</i>	0.2897	0.748	0.0912	6.2554	0.104	1.7451
<i>rdperint</i>	1.1653	0.048 **	0.3668	1.3896	0.039 **	0.3877
<i>IntoverD</i>	0.1262	0.003 ***	0.0397	0.2345	0.000 ***	0.0654
<i>HHI</i>	-1.0685	0.143	-0.3363	2.4148	0.027 **	0.6737
<i>phd_ma</i>	0.0067	0.093 *	0.0021	0.0006	0.728	0.0002
<i>ipicsec</i>	0.0004	0.646	0.0001	0.0025	0.018 **	0.0007

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI3: Wald chi2(6)=26.85 Prob > chi2=0.0002

For PCRI3: Wald chi2(6)=53.88 Prob > chi2=0.0000

The PCRI3 model focuses on the relationship between process innovation and *external R&D intensity*, which is shown in Table 263. In this model, independent variables are statistically significant at 10% level, except *external R&D intensity* and the *number of highly educated R&D personnel*. Hence, the null hypothesis, $H4b_0$, is not rejected. *R&D personnel intensity*, *HHI*, and *industrial production index by manufacturing industry* are statistically significant at 5% level. *Turnover* is statistically significant at 1% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.39 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 6.54 percent in the likelihood of occurrence of process innovation.

- An increase in *HHI* of 0.01, on average, leads to an increase of 0.67 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.07 percent in the likelihood of occurrence of process innovation.

Regression results of PDRI4 and PCRI4 models include coefficient, p-value, and average marginal effect, which are shown in Table 264. These models analyze the effect of *external-domestic R&D intensity* on the probability of product and process innovations, respectively.

Table 264: Regression Results of PDRI4 and PCRI4 Models – Large

Variable Name	PDRI4			PCRI4		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extdomrdint</i>	-0.0439	0.960	-0.0138	5.8491	0.413	1.6335
<i>rdperint</i>	1.2111	0.050 **	0.3813	1.4047	0.038 **	0.3923
<i>IntoverD</i>	0.1262	0.003 ***	0.0397	0.2334	0.000 ***	0.0652
<i>HHI</i>	-1.0717	0.141	-0.3374	2.4248	0.028 **	0.6772
<i>phd_ma</i>	0.0066	0.096 *	0.0021	0.0007	0.710	0.0002
<i>ipicsec</i>	0.0004	0.651	0.0001	0.0025	0.018 **	0.0007

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$.

For PDRI4: Wald $\chi^2(6)=26.67$ Prob > $\chi^2=0.0002$

For PCRI4: Wald $\chi^2(6)=52.16$ Prob > $\chi^2=0.0000$

The PDRI4 model focuses on the relationship between product innovation and *external-domestic R&D intensity*, which is shown in Table 264. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity*, *turnover*, and the *number of highly educated R&D personnel*. Hence, the null hypothesis, H_{2c0} , is not rejected. *R&D personnel intensity*, *turnover*, and the *number of highly educated R&D personnel* are statistically significant at 5%, 1%, and 10% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.38 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 3.97 percent in the likelihood of occurrence of product innovation.

- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.002 in the likelihood of occurrence of product innovation.

The PCRI4 model focuses on the relationship between process innovation and *external-domestic R&D intensity*, which is shown in Table 264. In this model, independent variables are statistically significant at 10% level, except *external-domestic R&D intensity* and the *number of highly educated R&D personnel*. Hence, the null hypothesis, $H4c_0$, is not rejected. *R&D personnel intensity*, *HHI*, and *industrial production index by manufacturing industry* are statistically significant at 5% level. *Turnover* is statistically significant at 1% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.39 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 6.52 percent in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 0.68 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.07 percent in the likelihood of occurrence of process innovation.

Regression results of PDRI5 and PCRI5 models include coefficient, p-value, and average marginal effect, which are shown in Table 265. These models analyze the effect of *external-foreign R&D intensity* on the probability of product and process innovations, respectively.

The PDRI5 model focuses on the relationship between product innovation and *external-foreign R&D intensity*, which is shown in Table 265. In this model, independent variables are not statistically significant at 10% level, except *R&D personnel intensity*, *turnover*, and the *number of highly educated R&D personnel*. Hence, the null hypothesis, $H2d_0$, is not rejected. *R&D personnel intensity*, *turnover*,

and the *number of highly educated R&D personnel* are statistically significant at 5%, 1%, and 10% level, respectively. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.38 in the likelihood of occurrence of product innovation.
- 1 percent increase in the value of *turnover*, on average, leads to an increase of 3.98 percent in the likelihood of occurrence of product innovation.
- A unit increase in the value of the *number of highly educated R&D personnel*, on average, leads to an increase of 0.002 in the likelihood of occurrence of product innovation.

Table 265: Regression Results of PDRI5 and PCRI5 Models – Large

Variable Name	PDRI5			PCRI5		
	Coef.	p-Value	dy/dx	Coef.	p-Value	dy/dx
<i>extfrgrdint</i>	2.2834	0.405	0.7186	21.804	0.180	6.0729
<i>rdperint</i>	1.1975	0.025 **	0.3769	1.5267	0.008 ***	0.4252
<i>IntoverD</i>	0.1266	0.003 ***	0.0398	0.2359	0.000 ***	0.0657
<i>HHI</i>	-1.0709	0.140	-0.3370	2.3957	0.027 **	0.6673
<i>phd_ma</i>	0.0066	0.098 *	0.0021	0.0005	0.764	0.0001
<i>ipicsec</i>	0.0004	0.646	0.0001	0.0025	0.017 **	0.0007

Note: For label of variables, please check Appendix 4. dy/dx is average marginal effects.

Significance level: * p<0.1 ** p<0.05 *** p<0.01.

For PDRI5: Wald chi2(6)=27.02 Prob > chi2=0.0001

For PCRI5: Wald chi2(6)=53.46 Prob > chi2=0.0000

The PCRI5 model focuses on the relationship between process innovation and *external-foreign R&D intensity*, which is shown in Table 265. In this model, independent variables are statistically significant at 10% level, except *external-foreign R&D intensity* and the *number of highly educated R&D personnel*. Hence, the null hypothesis, $H4d_0$, is not rejected. *R&D personnel intensity* and *turnover* are statistically significant at 1% level. *HHI* and *industrial production index by manufacturing industry* are statistically significant at 5% level. There are many results of this model, *ceteris paribus*, such as:

- A unit increase in the value of *R&D personnel intensity*, on average, leads to an increase of 0.43 in the likelihood of occurrence of process innovation.

- 1 percent increase in the value of *turnover*, on average, leads to an increase of 6.57 percent in the likelihood of occurrence of process innovation.
- An increase in *HHI* of 0.01, on average, leads to an increase of 0.67 in the likelihood of occurrence of process innovation.
- 1 percent increase in the value of *industrial production index by manufacturing industry*, on average, leads to an increase of 0.07 percent in the likelihood of occurrence of process innovation.

According to the analysis of Turkish manufacturing industry with large size firm, there are many findings in terms of product innovation. These are:

- R&D expenditure variables except external-domestic are statistically significant and have positive effects on the likelihood of occurrence of product innovation. It means that more of these expenditures increase the likelihood of occurrence of product innovation. The most effective expenditure type is *internal R&D expenditure*.
- R&D intensity variables are not statistically significant at 10% level.
- According to PDRE1 model, *HHI* is statistically significant and has negative effect on the likelihood of occurrence of product innovation. According to PDRI1 models, *R&D personnel intensity*, *turnover*, and the *number of highly educated R&D personnel* are statistically significant and have positive effects on the likelihood of occurrence of product innovation. It means that more *R&D personnel intensity*, more *turnover*, and more highly educated R&D personnel increase the likelihood of occurrence of product innovation, and more concentrated manufacturing industry with large size firms decreases it.

According to the analysis of Turkish manufacturing industry with large size firm, there are many findings in terms of process innovation. These are:

- R&D expenditure variables such as total and internal are statistically significant and have positive effects on the likelihood of occurrence of

process innovation. It means that more of these expenditures increase the likelihood of occurrence of process innovation. The most effective expenditure type is *internal R&D expenditure*.

- R&D intensity variables are not statistically significant at 10% level.
- According to PCRE1 model, *turnover*, *HHI*, and *industrial production index by manufacturing industry* are statistically significant and have positive effects on the likelihood of occurrence of process innovation. According to PCRI1 models, *R&D personnel intensity*, *turnover*, *HHI*, and *industrial production index by manufacturing industry* are statistically significant and have positive effects on the likelihood of occurrence of process innovation. It means that more *R&D personnel intensity*, more *turnover*, more concentrated manufacturing industry with large size firms, and more *industrial production index by manufacturing industry* increase the likelihood of occurrence of process innovation.

Results of the analyses are also viewed by comparing product and process innovation in terms of Turkish manufacturing industry with large size firm. These are:

- The impact of *total* and *internal R&D expenditures* on the likelihood of occurrence of product innovation are greater than their impacts on the likelihood of occurrence of process innovation.
- *External* and *external-foreign R&D expenditures* affect only the likelihood of occurrence of product innovation positively.

Results and findings from the analysis of Turkish manufacturing industry by firm size are presented here. The differences in terms of the effects of R&D expenditures and R&D intensities on the likelihood of occurrence of product and process innovations are investigated with the twenty models. The results of the analyses in terms of product and process innovation are summarized in Appendix 17 and 18, which presented many statistics about R&D expenditure and R&D intensity variables such as their positive or negative effects, their significance level, and their

average marginal effect. Results of the analyses are also viewed by comparing product and process innovation according to classifications.

The effects of the rest of independent variables such as *turnover*, *HHI*, the *number of highly educated R&D personnel*, and *industrial production index by manufacturing industry* are explained generally, especially by focusing on the PDRE1 and PDRI1 (product innovation models), and PCRE1 and PCRI1 (process innovation models). Because these models include two main and inclusive independent variables such as *total R&D expenditure* and *total R&D intensity*. To explain the results, the effects of R&D expenditure is interpreted in terms of percentages, and the effects of R&D intensity is interpreted in terms of units.

In this chapter, firms that engaged in R&D in Turkish manufacturing industry are analyzed to reveal the effect of independent variables on the likelihood of occurrence of product and process innovations, from the three perspectives by classifications in terms of TI, EII, and FS. The results of the analysis are interpreted in the shadow of theoretical framework, research methodology, and research design. These results are reported by product innovation, process innovation, and by comparing product and process innovation. The results of the analyses in terms of product innovation are tabulated in Appendix 13, 15, and 17. The results of the analyses in terms of process innovation are tabulated in Appendix 14, 16, and 18.

In the next chapter, conclusion of the research, policy recommendations, and suggestions for future study will be reported.

CONCLUSION AND SUGGESTIONS

Technological innovations and developments have been seen since time immemorial, especially in the last two centuries (particularly in the 20th century) increasingly after the Industrial Revolution. Together with new innovations, the world transformed into a kind of village and technology became a part of life and a source of economic development and growth.

In classical growth theory, economic growth is based on the accumulation of capital and savings. It is seen that economic growth is related to the availability of land, labor, and capital. The neoclassical growth theory also extended the classical one by focusing on the importance of technological progress that enhances productivity, thereby triggers economic growth. According to Solow-Swan model, output and capital stock will continue to expand but only at the same pace as population growth in the steady state equilibrium, and increasing the saving rate can lead to a temporary boost in the growth rate of the economy (output per capita) but this enhanced growth is not sustainable in the long run (Aghion and Howitt, 2009). Introducing technological progress to this Solow-Swan model is important for generation of sustained economic growth. Therefore, in the long-run, countries experience growth of capital per capita at the rate of technological progress, supposing that technological progress took place externally or outside of the model.

By focusing on development of long-run economic growth model, Romer (1986) stated knowledge as a key factor that has positive effect on marginal productivity, in other words, knowledge increases marginal productivity in the long-term for economic growth. According to Lucas (1988) emphasized that knowledge accumulation is a source for sustainable economic growth. Romer (1987, 1990), Aghion and Howitt (1992), and Grossman and Helpman (1991a, 1991b, 1991c)] are focused on the determination of endogenous economic growth models in terms of the integration among the neoclassical economic growth model, R&D theories, and imperfect competition framework. By focusing on R&D, Romer (1990) precisely inserted R&D sector in the economic growth model and emphasized that some parts

of human capital is separated for research. These developments are actually based on the former thoughts, for instance, Maclaurin (1950a) discussed the process of innovation and entrepreneurship by emphasizing the importance of scientific entrepreneurship and scientists, and Phelps (1966) separated researchers (as investment in technology) from labor force and stated that increase in productivity of researchers causes technological progress. Romer (1990) emphasized also that the existing stock of ideas influences the productivity of research.

Nelson and Phelps (1966) emphasized the importance of education that enhances learning capability of human capital and therefore educated labor or manager may accelerate adaptation of a firm to technological change and technological diffusion by introducing new production processes. Cohen and Levinthal (1989) emphasized that simplicity and structure of the learning process is significant for R&D expenditure and technological opportunities. Cohen and Levinthal (1990) shed light on learning and innovation and stated that the learning environment of firms is significant in terms of R&D and its absorptive capacity. According to Romer (1993), human capital and institutional framework based on educational system, firms, and R&D institutions are two important sources of absorption capability that is one of the characteristics of an economy in terms of endogenous growth theory. For instance, Foster and Rosenzweig (1996) showed that in India, educated labor catches on quicker and is more compatible with new technologies when compared with less educated labor, and there is a complementary relationship between technical change and investment in education.

Abilities, skills, and knowledge of workers and researchers can be increased with a formal education system that supports economic growth. R&D and research provide the accumulation of knowledge through researchers, scientists, engineers, and technicians, so a formal and productive education system is needed to increase their number and quality (Hayami and Godo, 2005). For instance, Sanchez-Sellero et al. (2015) showed that in Spain, if firms carry on their R&D activities in collaboration with universities, technology centers and if firms employ new graduates who studied in science, engineering, or technology and who are endowed with latest scientific knowledge, they give an outstanding performance with higher productivity.

Under these discussions in literature, in the twentieth century, R&D activities have increased dramatically decade by decade especially under the military aims and R&D expenditure increased generally during both the World Wars. After WWII, countries have increased their R&D expenditure dramatically to innovate new technologies and to research in many fields such as ICT, transportation, biotechnology, aerospace, defense, electronics etc. for their competitiveness and economic growth and development.

The best method among them for a country is to produce its own technology by performing R&D activities. R&D activities are a key source of long-run productivity and welfare through innovation (Jones and Williams, 2000). Subventions for innovation stimulate economic growth through R&D activities (Segerstrom, 1990). Investment in R&D to produce its own technology supports economic growth through the instrument of innovations (Shefer and Frenkel, 2005).

The most important source of economic development and growth is technological progress thanks to inventions and innovations resulting from R&D activities. A country must produce its own technology by performing R&D activities. R&D activities are a key source of long-run productivity and welfare through innovation (Jones and Williams, 2000). Subventions for innovation stimulate economic growth through R&D activities (Segerstrom, 1990). Investment in R&D to produce its own technology supports economic growth through the instrument of innovations (Shefer and Frenkel, 2005). That is why policies on R&D, S&T, and innovation must be determined strategically. However, determination of these policies requires comprehensive research on R&D and technology. Therefore, Frascati Manual in 1963 and Oslo Manual in 1992 were published as a methodology for the research (OECD, 1963, 1992). In the shadow of these Manuals, in Türkiye, TURKSTAT conducts Community Innovation Survey to reveal innovation statistics, like other countries. Türkiye tends to focus on improving its industrial structure and technology more in recent years.

In this dissertation, in order to support determination process of S&T, R&D, and innovation policies in Türkiye, firms with 20 and more than 20 employees that are

engaged in R&D in Turkish manufacturing industry are analyzed to investigate the effect of R&D expenditure and R&D intensity on the likelihood of occurrence of product and process innovation in the period between 2009 and 2016. This analysis is performed from five different perspectives such as: as a whole (by section C in NACE Rev. 2); by sectors (by division in NACE Rev. 2 2-digit); technology intensity classification (TI); education intensity classification (EII); and firm size classification (FS). The effects of ten different main independent variables (breakdowns of R&D expenditure and R&D intensity) such as total, internal, external, external-domestic, and external-foreign on the likelihood of the occurrence of product and process innovation are investigated. Therefore, twenty models are used to avoid multicollinearity. A panel data is generated to analyze the firms, by using four different micro data sets that are provided by TURKSTAT (such as IS, AISS, RDAS). Population-averaged panel data model (marginal effect model) is applied with robust standard error method, within-unit exchangeable correlation structure, and 90 percent confidence level.

Total R&D expenditure is the sum of internal and external R&D expenditures. Internal R&D expenditure is all expenditures for R&D activities within the firm. With internal R&D expenditure, firms can internalize knowledge under many motivations such as high efficiency and cost reductions in the long term. External R&D expenditure is all expenditures for R&D activities that are carried out by other institutions/organizations (e.g., higher education institutions, universities, other firms) in Türkiye and/or on abroad. With external R&D expenditure, firms prefer to use experiences of other institutions/organizations/firms by giving up knowledge (unprotected and inappropriate), and ability to control innovation management process. External R&D expenditure is separated into two parts such as external-domestic R&D expenditure and external-foreign R&D expenditure. Because there are five different R&D expenditures as independent variables, R&D intensity variable is also separated into five different types such as total, internal, external, external-domestic, and external-foreign. These R&D intensities are used as an indicator of R&D investment. R&D personnel intensity is used as an indicator of know-how. The other independent variables such as turnover, HHI, the number of highly educated R&D

personnel, and industrial production index by manufacturing industry. It is hypothesized that all these variables increase the likelihood of occurrence of product and process innovation in Turkish manufacturing industry.

In general, this study emphasized the importance of sectoral differences and of research on sectors. Moreover, results of the dissertation showed that there are differences in results with respect to sectors, innovation types, R&D expenditure types, R&D intensity types, classifications such as technology intensity (TI), education intensity (EII), and firm size (FS). These results of the analysis of Turkish manufacturing industry from the five perspectives are interpreted in Chapter IV, V, and VI, which provide results in detail.

In terms of Turkish manufacturing industry by section C (as a whole), general results are interpreted below by focusing on R&D expenditure and R&D intensity variables:

- All R&D expenditures except *external-foreign R&D expenditure* have positive effect on the likelihood of occurrence of product innovation while all R&D expenditures except *external-domestic R&D expenditure* have positive effect on the likelihood of occurrence of process innovation.
- All R&D intensities except *internal R&D intensity* have positive effect on the likelihood of occurrence of product innovation while all external R&D intensities have positive effect on the likelihood of occurrence of process innovation.
- The impact of *total R&D expenditure* on the likelihood of occurrence of process innovation is greater than its impact on the likelihood of occurrence of product innovation.
- The impacts of *internal* and *external R&D expenditures* on the likelihood of occurrence of product innovation are greater than its impact on the likelihood of occurrence of process innovation.
- *External-domestic R&D expenditure* affects only the likelihood of occurrence of product innovation positively.

- *External-foreign R&D expenditure* affects only the likelihood of occurrence of process innovation positively while *total R&D intensity* affects only the likelihood of occurrence of product innovation positively.
- The impact of *external*, *external-domestic*, and *external-foreign R&D intensity* on the likelihood of occurrence of process innovation is greater than its impact on the likelihood of occurrence of product innovation.

In terms of Turkish manufacturing industry by division (industries), general results are interpreted below by focusing on R&D expenditure and R&D intensity variables:

- *In manufacture of food products-10*, the effects of R&D expenditures on the likelihood of occurrence of product and process innovation are not statistically significant. Moreover, *external-foreign R&D intensity* has positive effect on the likelihood of occurrence of product innovation while *external-domestic R&D intensity* has negative effect on the likelihood of occurrence of process innovation because there is fishing-out case.
- *In manufacture of textiles-13*, *total* and *internal R&D expenditure* have positive effect on the likelihood of occurrence of product innovation while the effects of all R&D expenditures on the likelihood of occurrence of process innovation are not statistically significant. Moreover, all R&D intensities have positive effect on the likelihood of occurrence of product innovation while only *external-domestic* and *external-foreign R&D intensity* have positive effect on the likelihood of occurrence of process innovation. The impact of *external-domestic R&D intensity* on the likelihood of occurrence of product innovation is greater than its impact on the likelihood of occurrence of process innovation. The impact of *external-foreign R&D intensity* on the likelihood of occurrence of process innovation is greater than its impact on the likelihood of occurrence of product innovation.
- *In manufacture of chemicals and chemical products-20*, all external R&D expenditures have negative effect on the likelihood of occurrence of

product innovation because there is fishing-out case while the effects of all R&D expenditures on the likelihood of occurrence of process innovation are not statistically significant. Moreover, the effects of all R&D intensities on the likelihood of occurrence of product innovation are not statistically significant while only external-foreign R&D intensity has positive effect on the likelihood of occurrence of process innovation.

- *In manufacture of basic pharmaceutical products and pharmaceutical preparations-21, external and external-domestic R&D expenditure have positive effect on the likelihood of occurrence of product innovation while total, external, and external-domestic R&D expenditure have positive effect on the likelihood of occurrence of process innovation. Moreover, all external R&D intensities have positive effect on the likelihood of occurrence of product innovation while all R&D intensities have positive effect on the likelihood of occurrence of process innovation. The impact of external and external-domestic R&D expenditure on the likelihood of occurrence of product innovation is greater than its impact on the likelihood of occurrence of process innovation. Total R&D expenditure affects only the likelihood of occurrence of process innovation. The impact of external and external-domestic R&D intensity on the likelihood of occurrence of process innovation is greater than its impact on the likelihood of occurrence of product innovation. The impact of external-foreign R&D intensity on the likelihood of occurrence of product innovation is greater than its impact on the likelihood of occurrence of process innovation.*
- *In manufacture of rubber and plastic products-22, external and external-foreign R&D expenditure have positive effect on the likelihood of occurrence of product innovation while the effects of all R&D expenditures on the likelihood of occurrence of process innovation are not statistically significant. Moreover, the effects of all R&D intensities on product and the likelihood of occurrence of process innovation are not statistically significant.*

- *In manufacture of other non-metallic mineral products-23, total and internal R&D expenditure* have positive the likelihood of occurrence of product and process innovation. Moreover, only *external-domestic R&D intensity* has positive effect on the likelihood of occurrence of product innovation while the effects of all R&D intensities on the likelihood of occurrence of product and process innovation are not statistically significant. The impact of *total* and *internal R&D expenditures* on the likelihood of occurrence of product innovation is greater than its impact on the likelihood of occurrence of process innovation.
- *In manufacture of basic metals-24, total and internal R&D expenditure* have positive effect on the likelihood of occurrence of product and process innovation. The impact of *total* and *internal R&D expenditure* on the likelihood of occurrence of product innovation is greater than its impact on the likelihood of occurrence of process innovation. Moreover, *total, internal, and external-foreign R&D intensity* have positive effect on the likelihood of occurrence of product innovation but *external-domestic R&D intensity* has negative effect on it because there is fishing-out case. In addition, all external R&D intensities have positive effect on the likelihood of occurrence of process innovation. *Total* and *internal R&D intensity* affect only the likelihood of occurrence of product innovation positively. *External R&D intensity* affects only the likelihood of occurrence of process innovation positively. The impact of *external-domestic* and *external-foreign R&D intensity* on the likelihood of occurrence of process innovation is greater than its impact on the likelihood of occurrence of product innovation.
- *In manufacture of fabricated metal products, except machinery and equipment-25, total, internal, and external-domestic R&D expenditure* have positive effect on the likelihood of occurrence of product innovation while the effects of all R&D expenditures on the likelihood of occurrence of process innovation are not statistically significant. Moreover, *total, internal, external, and external-domestic R&D intensity* have positive

effect on the likelihood of occurrence of product innovation while *external-foreign R&D intensity* has negative effect on the likelihood of occurrence of process innovation because there is fishing-out case.

- *In manufacture of computer, electronic and optical products-26*, *total*, *internal*, and *external-foreign R&D expenditure* have positive effect on the likelihood of occurrence of product innovation while *total* and *internal R&D expenditure* have negative effect on the likelihood of occurrence of process innovation because there is fishing-out case. Moreover, *external-foreign R&D intensity* has positive effect on the likelihood of occurrence of product innovation while *external* and *external-domestic R&D intensity* have positive effect on the likelihood of occurrence of process innovation. *Total* and *internal R&D expenditure* affect the likelihood of occurrence of product innovation positively, but the likelihood of occurrence of process innovation negatively.
- *In manufacture of electrical equipment-27*, *internal R&D expenditure* has positive effect on the likelihood of occurrence of product innovation while the effects of all R&D expenditures on the likelihood of occurrence of process innovation are not statistically significant. Moreover, the effects of all R&D intensities on the likelihood of occurrence of product and process innovation are not statistically significant.
- *In manufacture of machinery and equipment n.e.c.-28*, the effects of all R&D expenditures on the likelihood of occurrence of product and process innovation are not statistically significant. Moreover, the effect of all external R&D intensities have positive effect on the likelihood of occurrence of product innovation while *external-foreign R&D intensity* has positive effect on the likelihood of occurrence of process innovation. The impact of *external-foreign R&D intensity* on the likelihood of occurrence of process innovation is greater than its impact on the likelihood of occurrence of product innovation.

- *In manufacture of motor vehicles, trailers and semi-trailers-29, total, internal, external, and external-foreign R&D expenditure have positive effect on the likelihood of occurrence of product innovation while total, internal, external, and external-domestic R&D expenditure have positive effect on the likelihood of occurrence of process innovation. Moreover, external-foreign R&D intensity has positive effect on the likelihood of occurrence of product innovation while external and external-domestic R&D intensity have positive effect on the likelihood of occurrence of process innovation. The impact of total and internal R&D expenditures on the likelihood of occurrence of process innovation are greater than its impact on the likelihood of occurrence of product innovation. The impact of external R&D expenditure on the likelihood of occurrence of product innovation is greater than its impact on the likelihood of occurrence of process innovation.*

In terms of Turkish manufacturing industry by technology intensity classification, general results are interpreted below by focusing on R&D expenditure and R&D intensity variables:

- *In HT industries, external R&D expenditure has positive effect on the likelihood of occurrence of product innovation while the effects of all R&D expenditures on the likelihood of occurrence of process innovation are not statistically significant. Moreover, the effects of all R&D intensities on the likelihood of occurrence of product innovation are not statistically significant while total, external, external-domestic, and external-foreign R&D intensity have positive effect on the likelihood of occurrence of process innovation.*
- *In MHT industries, total and internal R&D expenditure have positive effect on the likelihood of occurrence of product and process innovation. The impact of total and internal R&D expenditures on the likelihood of occurrence of product innovation are greater than their impacts on the likelihood of occurrence of process innovation. Moreover, the effects of all*

R&D intensities on the likelihood of occurrence of product innovation are not statistically significant while *external-foreign R&D intensity* has positive effect on the likelihood of occurrence of process innovation.

- *In MLT industries, total and internal R&D expenditure* have positive effect on the likelihood of occurrence of product and process innovation. The impact of *total and internal R&D expenditures* on the likelihood of occurrence of product innovation are greater than their impacts on the likelihood of occurrence of process innovation. Moreover, *total, internal, external, and external-domestic R&D intensity* have positive effect on the likelihood of occurrence of product innovation while *external and external-domestic R&D intensity* have positive effect on the likelihood of occurrence of process innovation. The impact of *external R&D intensity* on the likelihood of occurrence of product innovation is greater than its impact on the likelihood of occurrence of process innovation. The impact of *external-foreign R&D intensity* on the likelihood of occurrence of product innovation is like its impact on the likelihood of occurrence of process innovation.
- *In LT industries, total, internal, external, and external-foreign R&D expenditure* have positive effect on the likelihood of occurrence of product innovation while *total, internal, and external-foreign R&D expenditure* have positive effect on the likelihood of occurrence of process innovation. The impact of *external-foreign R&D expenditure* on the likelihood of occurrence of process innovation is greater than its impact on the likelihood of occurrence of product innovation. Moreover, *total, internal, and external-foreign R&D intensity* have positive effect on the likelihood of occurrence of product innovation while *external and external-domestic R&D intensities* have positive effect on the likelihood of occurrence of process innovation.

In terms of Turkish manufacturing industry by education intensity classification, general results are interpreted below by focusing on R&D expenditure and R&D intensity variables:

- *In industries with HEI, total and internal R&D expenditure* have positive effect on the likelihood of occurrence of product innovation while the effects of all R&D expenditures on the likelihood of occurrence of process innovation are not statistically significant. Moreover, the effects of all R&D intensities on the likelihood of occurrence of product innovation are not statistically significant while *external* and *external-domestic R&D intensity* have positive effect on the likelihood of occurrence of process innovation.
- *In industries with MHEI, total and internal R&D expenditures* have positive effect on the likelihood of occurrence of product and process innovation. Moreover, the effects of all R&D intensities on the likelihood of occurrence of product innovation are not statistically significant while *external-foreign R&D intensity* has positive effect on the likelihood of occurrence of process innovation.
- *In industries with MLEI, total, internal, external, and external-foreign R&D expenditure* have positive effect on the likelihood of occurrence of product innovation while *total* and *internal R&D expenditure* have positive effect on the likelihood of occurrence of process innovation. The impact of *total* and *internal R&D expenditure* on the likelihood of occurrence of product innovation are greater than their impacts on the likelihood of occurrence of process innovation. Moreover, *external* and *external-foreign R&D intensity* have positive effect on the likelihood of occurrence of product innovation while the effects of all R&D intensities on the likelihood of occurrence of process innovation are not statistically significant. *External* and *external-foreign R&D expenditure*, and *external* and *external-foreign R&D intensity* affect only the likelihood of occurrence of product innovation positively.

- *In industries with LEI, external-foreign R&D expenditure* has positive effect on the likelihood of occurrence of product innovation while *total, internal, and external-foreign R&D expenditure* have positive effect on the likelihood of occurrence of process innovation. The impact of *external-foreign R&D expenditure* on the likelihood of occurrence of process innovation is greater than its impact on the likelihood of occurrence of product innovation. Moreover, *external-foreign R&D intensity* has positive effect on the likelihood of occurrence of product innovation while *total, internal, external-domestic, and external-foreign R&D intensity* have positive effect on the likelihood of occurrence of process innovation. The impact of *external-foreign R&D intensity* on the likelihood of occurrence of process innovation is greater than its impact on the likelihood of occurrence of product innovation.

In terms of Turkish manufacturing industry by firm size classification, general results are interpreted below by focusing on R&D expenditure and R&D intensity variables:

- *In industries with small firms*, the effects of all R&D expenditures on the likelihood of occurrence of product innovation are not statistically significant while *external-foreign R&D expenditure* has positive effect on the likelihood of occurrence of process innovation. Moreover, all external R&D intensities have positive effect on the likelihood of occurrence of product and process innovation. The impact of *external, external-domestic, and external-foreign R&D intensity* on the likelihood of occurrence of process innovation are greater than their impacts on the likelihood of occurrence of product innovation.
- *In industries with medium-sized firms*, *total and internal R&D expenditure* have positive effect on the likelihood of occurrence of product innovation while *total and external-foreign R&D expenditure* have positive effect on the likelihood of occurrence of process innovation. The impact of *total R&D expenditure* on the likelihood of occurrence of product innovation are

greater than its impact on the likelihood of occurrence of process innovation. Moreover, all R&D intensities have positive effect on the likelihood of occurrence of product and process innovation. The impact of *total*, *internal*, *external*, and *external-domestic R&D intensity* on the likelihood of occurrence of product innovation are greater than their impacts on the likelihood of occurrence of process innovation. The impact of *external-foreign R&D intensity* on the likelihood of occurrence of process innovation is greater than its impact on the likelihood of occurrence of product innovation.

- *In industries with large firms, total, internal, external, and external-foreign R&D expenditure* have positive effect on the likelihood of occurrence of product innovation while *total* and *internal R&D expenditure* have positive effect on the likelihood of occurrence of process innovation. The impact of *total* and *internal R&D expenditures* on the likelihood of occurrence of product innovation are greater than their impacts on the likelihood of occurrence of process innovation. Moreover, the effects of all R&D intensities on the likelihood of occurrence of product and process innovation are not statistically significant.

Detailed results are interpreted at the end of Chapter IV, Chapter V, and Chapter VI. Results given here are focused on the effect of R&D expenditure and R&D intensity variables on the likelihood of occurrence of product and process innovation.

According to the results, in general, policies are recommended for Türkiye such as:

- i) In Turkish manufacturing industry, R&D expenditure and R&D intensity must be increased to support product and process innovation by regarding the sectoral differences, classifications, R&D expenditure types, and innovation types. In other words, in terms of the results, this study showed that in Turkish manufacturing industry, there are differences by sectors, by technology intensity, by education intensity, by firm size, by R&D expenditure types, by R&D intensity types, and by innovation types.

- ii) The number of R&D personnel must be increased to enhance adaptability of firm/sector to technology and to increase the likelihood of occurrence of product and process innovation. Türkiye imports recent technologies (e.g., industry 4.0 related) from developed countries but many of them are not used with full performance because of the lack of technical personnel, laws, and the ability of adaptability. Thus, the ability of adaptability by sector is strongly needed for a powerful economic development so it must be realized.
- iii) Efficient education system is needed for a sustainable innovative culture in the country. Especially, it is a strategic system to grow more researchers, scientists, educated workers and managers. So, efficient education system must be generated in the country.
- iv) Technological infrastructures and technology level of institutions must be updated consistently for acceleration of R&D activities.

As a conclusion, in Turkish manufacturing industry as a whole, manufacturing firms that are engaged in R&D must increase their total R&D expenditure (internal and external) to increase the likelihood of occurrence of product innovation and process innovation. Additionally, these firms must also increase their external-domestic R&D expenditure to increase the likelihood of occurrence of product innovation while they must increase their external-foreign R&D expenditure to increase the likelihood of occurrence of process innovation. However, internal R&D expenditure is more effective than others expenditure to increase the likelihood of occurrence of both innovation types.

Moreover, from the technology intensity perspective, firms that are engaged in R&D in MHT, MLT, and LT industries must increase their total and internal R&D expenditure to increase the likelihood of occurrence of product innovation and process innovation. These firms in HT industries must increase external R&D expenditure to increase the likelihood of occurrence of product innovation. From the education intensity perspective, firms that are engaged in R&D in HEI, MHEI, and MLEI industries must increase their total and internal R&D expenditure to increase the

likelihood of occurrence of product innovation while these firms in MHEI, MLEI, and LEI industries must increase their total and internal R&D expenditure to increase the likelihood of occurrence of process innovation. From the firm size perspective, medium and large firms that are engaged in R&D must increase their total R&D expenditure to increase the likelihood of occurrence of product innovation and process innovation. These firms must increase their internal R&D expenditure to increase the likelihood of occurrence of product innovation. Moreover, only large firms must increase their internal R&D expenditure to increase the likelihood of occurrence of process innovation.

This dissertation has many limitations such as dummy variable problem, change in the structure of CIS (Community Innovation Survey), limited data from TURKSTAT, and data confidentiality. According to dummy variable problem, because product and process innovation are represented by a dummy variable, measurement of innovation is complicated so dummy variables may provide biased results. Changes in the structure of CIS are obstacles to comparing surveys with previous ones, that is why the analysis covers the period until 2016. There is limited data from TURKSTAT, that is why the analysis covers the period from 2009. Data confidentiality may be the strongest one. The micro data sets that are provided by TURKSTAT are confidential data and it is not possible to take and share it. Only the results of the analysis (analysis tables) are given to the researcher but if they approve.

Recommendations for researchers is important for future studies. In the future, Turkish manufacturing industry by NACE Rev. 2 2-digit (division) can be investigated in detail more in terms of product and process innovation, R&D expenditure, and R&D intensity. Moreover, the industry can be analyzed in detail regarding 3-digit, 4-digit, and 6-digit of NACE Rev 2. In addition, the effect of R&D expenditure and R&D intensity on other innovation types such as marketing and organizational innovation, and interaction between product and process innovations in Turkish manufacturing industry can be investigated.

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APPENDIX

Appendix 1: Classification of Manufacturing Industry by NACE Rev. 2

C	Manufacturing Industry
10	Manufacture of food products
11	Manufacture of beverages
12	Manufacture of tobacco products
13	Manufacture of textiles
14	Manufacture of wearing apparel
15	Manufacture of leather and related products
16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
17	Manufacture of paper and paper products
18	Printing and reproduction of recorded media
19	Manufacture of coke and refined petroleum products
20	Manufacture of chemicals and chemical products
21	Manufacture of basic pharmaceutical products and pharmaceutical preparations
22	Manufacture of rubber and plastic products
23	Manufacture of other non-metallic mineral products
24	Manufacture of basic metals
25	Manufacture of fabricated metal products, except machinery and equipment
26	Manufacture of computer, electronic and optical products
27	Manufacture of electrical equipment
28	Manufacture of machinery and equipment n.e.c.
29	Manufacture of motor vehicles, trailers and semi-trailers
30	Manufacture of other transport equipment
31	Manufacture of furniture
32	Other manufacturing
33	Repair and installation of machinery and equipment

Source: EUROSTAT, 2008. Based on NACE Rev. 2 at 2-digit level.

Appendix 2: Technology Intensity Classification of Manufacturing Industry

TI	C	Manufacturing Industry
HT	21	Manufacture of basic pharmaceutical products and pharmaceutical preparations
	26	Manufacture of computer, electronic and optical products
MHT	20	Manufacture of chemicals and chemical products
	27	Manufacture of electrical equipment
	28	Manufacture of machinery and equipment n.e.c.
	29	Manufacture of motor vehicles, trailers and semi-trailers
	30	Manufacture of other transport equipment
MLT	19	Manufacture of coke and refined petroleum products
	22	Manufacture of rubber and plastic products
	23	Manufacture of other non-metallic mineral products
	24	Manufacture of basic metals
	25	Manufacture of fabricated metal products, except machinery and equipment
	33	Repair and installation of machinery and equipment
LT	10	Manufacture of food products
	11	Manufacture of beverages
	12	Manufacture of tobacco products
	13	Manufacture of textiles
	14	Manufacture of wearing apparel
	15	Manufacture of leather and related products
	16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
	17	Manufacture of paper and paper products
	18	Printing and reproduction of recorded media
	31	Manufacture of furniture
	32	Other manufacturing

Source: EUROSTAT, 2022. Based on NACE Rev. 2 at 2-digit level. HT: High Technology; MHT: Medium-High Technology; MLT: Medium-Low Technology; and LT: Low Technology. Table is sorted by TI.

Appendix 3: Education Intensity Classification of Manufacturing Industry

Group	EII	C	Manufacturing Industry
HEI	1	29	Manufacture of motor vehicles, trailers and semi-trailers
	0.927622	26	Manufacture of computer, electronic and optical products
	0.589253	27	Manufacture of electrical equipment
MHEI	0.390916	30	Manufacture of other transport equipment
	0.366598	28	Manufacture of machinery and equipment n.e.c.
	0.245726	20	Manufacture of chemicals and chemical products
	0.245523	25	Manufacture of fabricated metal products, except machinery and equipment
	0.225811	21	Manufacture of basic pharmaceutical products and pharmaceutical preparations
MLEI	0.196839	10	Manufacture of food products
	0.184229	13	Manufacture of textiles
	0.15855	22	Manufacture of rubber and plastic products
	0.132956	23	Manufacture of other non-metallic mineral products
	0.107259	24	Manufacture of basic metals
LEI	0.047725	14	Manufacture of wearing apparel
	0.033338	31	Manufacture of furniture
	0.024609	19	Manufacture of coke and refined petroleum products
	0.021383	32	Other manufacturing
	0.016751	17	Manufacture of paper and paper products
	0.016132	33	Repair and installation of machinery and equipment
	0.005715	18	Printing and reproduction of recorded media
	0.003682	16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
	0.002064	15	Manufacture of leather and related products
	0	11	Manufacture of beverages

Source: Calculated and classified by Author. Education Intensity Index (EII) is calculated by using education level of R&D personnel data from TURKSTAT. The manufacturing industry clustered by EII with cluster analysis. HEI: High Education Intensity; MHEI: Medium-High Education Intensity; MLEI: Medium-Low Education Intensity; LEI: Low Education Intensity. Table is sorted by EII.

Appendix 4: Name, Label, and Details of Variables

Variable Name	Variable Label	Details
prod_in	Product Innovation (Pd)	Binary Dependent Variable
proc_in	Process Innovation (Pc)	Binary Dependent Variable
IntrdexpD	Total R&D Expenditure	Inflation-Adjusted and in Natural Logarithm “ln”
IntintrdexpD	Internal R&D Expenditure	
IntextrdexpD	External R&D Expenditure	
IntextrdexpdomD	External-Domestic R&D Expenditure	
IntextrdexpforD	External-Foreign R&D Expenditure	
totrdint	Total R&D Intensity	$\frac{\text{R\&D Expenditure}}{\text{Turnover}}$
intrdint	Internal R&D Intensity	
extrdint	External R&D Intensity	
extdomrdint	External-Domestic R&D Intensity	
extfrgrdint	External-Foreign R&D Intensity	
rdpersint	R&D Personnel Intensity	$\frac{\text{Total R\&D Personnel Number}}{\text{Total Personnel Number}}$
IntoverD	Turnover	Inflation-Adjusted and in Natural Logarithm “ln”
HHI	Herfindahl-Hirschman Index (HHI)	Calculated from AISS micro data set
phd_ma	The Number of Highly Educated R&D Personnel	PhD + MA (Highly Educated)
ipicsec	Industrial Production Index by Manufacturing Industry	Unadjusted, Yearly Average, 2009=100

Source: Prepared by Author.

Appendix 5: Correlation Matrix Among Independent Variables

	prod_in	proc_in	proc_in	intndexpD	intndexpD	intextndexpD	intextndexpD	intextndexpD	intextndexpD	intextndexpD	totrdint	intndint	extrndint	extdowntndint	extrgrdint	rdpresint	IntoverD	hhi	phd_mna	ipresc
prod_in	1																			
proc_in	0.4063	1																		
	0.0000		1																	
intndexpD	0.2094	0.2076		1																
	0.0000	0.0000			1															
intndexpD	0.2079	0.2051		0.9928		1														
	0.0000	0.0000					1													
intextndexpD	0.0905	0.075		0.3193		0.2639		1												
	0.0000	0.0000		0.0000		0.0000			1											
intextndexpD	0.0000	0.0000		0.0000		0.0000		0.0000		1										
intextndexpD	0.0756	0.0614		0.2893		0.2391		0.9254			1									
	0.0000	0.0001		0.0000		0.0000		0.0000				1								
intextndexpD	0.079	0.0908		0.2934		0.2669		0.6429		0.4402				1						
	0.0000	0.0000		0.0000		0.0000		0.0000		0.0000					1					
totrdint	0.0258	0.0205		0.0859		0.0843		0.0675		0.0719					0.6806					
	0.0962	0.1867		0.0000		0.0000		0.0000		0.0000						1				
intndint	0.0245	0.0192		0.0824		0.0829		0.0563		0.0613					0.0009	0.9978				
	0.1146	0.2163		0.0000		0.0000		0.0003		0.0001					0.9549	0.0000				
extrndint	0.0272	0.025		0.0775		0.0459		0.1785		0.1724					0.0793	0.3589	0.2959			
	0.0798	0.1078		0.0000		0.0031		0.0000		0.0000					0.0000	0.0000	0.0000			
extdowntndint	0.0216	0.0194		0.0567		0.0316		0.1453		0.161					0.0211	0.3639	0.3023	0.982		
	0.1633	0.2103		0.0003		0.0415		0.0000		0.0000					0.1734	0.0000	0.0000	0.0000		
extrgrdint	0.0325	0.032		0.1188		0.0804		0.1976		0.0852					0.3109	0.0294	0.0125	0.2457	0.0582	
	0.036	0.0389		0.0000		0.0000		0.0000		0.0000					0.0000	0.0585	0.4203	0.0000	0.0002	
rdpresint	0.0505	0.0356		0.1986		0.2004		0.0586		0.0653					0.0243	0.5044	0.4994	0.2343	0.2325	0.045
	0.0011	0.0216		0.0000		0.0000		0.0002		0.0000					0.1174	0.0000	0.0000	0.0000	0.0000	0.0037
IntoverD	0.1073	0.1764		0.5604		0.5587		0.1754		0.1673					0.1765	-0.1388	-0.1358	-0.0877	-0.0921	0.009
	0.0000	0.0000		0.0000		0.0000		0.0000		0.0000					0.0000	0.0000	0.0000	0.0000	0.0000	-0.3287
hhi	0.0297	0.0371		0.0364		0.0345		0.0622		0.0663					0.0722	-0.0003	-0.002	0.0241	0.0224	0.0128
	0.0559	0.0167		0.019		0.0263		0.0001		0.0000					0.0000	0.9865	0.8977	0.1196	0.1492	0.4101
phd_mna	0.0609	0.0585		0.3438		0.3452		0.1043		0.1054					0.12	0.034	0.0338	0.0139	0.006	0.0427
	0.0001	0.0002		0.0000		0.0000		0.0000		0.0000					0.0000	0.0284	0.0293	0.3713	0.7008	0.0059
ipresc	0.0455	0.0586		0.0802		0.0807		-0.02		-0.003					-0.0365	-0.006	-0.0072	0.0149	0.0134	0.0097
	0.0034	0.0002		0.0000		0.0000		0.1985		0.848					0.0187	0.7004	0.644	0.338	0.3875	0.5336
																				0.0000
																				0.0000
																				0.2287
																				0.1301
																				1

Note: Label of variables are explained in Appendix 4 and 6.

Appendix 6: Descriptive Statistics of Data

Variable Label	Variable	Obs	Mean	Std. Dev.	Min	Max
Firm ID	i	4,155	586.6469	334.678	1	1219
Year	t	4,155	2012.699	2.15959	2009	2016
Industry (NACE Rev. 2.) and Classifications	j	4,155	22.43153	6.304908	10	33
Number of Employee	noemp	4,155	758.5362	1290.079	20	16984
Education Intensity Index Classification	eiigr	4,155	2.301083	0.9330431	1	4
Technology Intensity Classification	tech_gr	4,155	2.669555	0.9583652	1	4
Firm Size Classification	sizegr	4,155	2.380987	0.8094736	1	3
Product Innovation (PD)	prod_in	4,155	0.7350181	0.4413767	0	1
Process Innovation (PC)	proc_in	4,155	0.7583634	0.4281267	0	1
Total R&D expenditure	Intrexpd	4,155	13.32107	1.746828	7.760927	20.14096
Internal R&D expenditure	IntintrdexPD	4,155	13.28304	1.736072	7.760927	20.13278
External R&D expenditure	IntextrdexPD	4,155	1.917051	4.393615	0	18.43079
External-domestic R&D expenditure	IntextrdexpdD	4,155	1.644487	4.036934	0	17.5184
External-foreign R&D expenditure	Intextrdexford	4,155	0.7685976	2.972171	0	18.42295
Total R&D intensity	tordint	4,155	0.0405117	0.4740248	0.0000276	18.61829
Internal R&D intensity	intrdint	4,155	0.0384147	0.463193	0.0000208	18.28734
External R&D intensity	extrdint	4,155	0.002097	0.03305	0	1.423363
External-domestic R&D intensity	extrdomdint	4,155	0.0016982	0.0320912	0	1.423363
External-foreign R&D intensity	extrfgdint	4,155	0.0003979	0.0062532	0	0.2461029
R&D Personnel Intensity	rdpersint	4,155	0.0699854	0.1183786	0.0002658	2.75
Turnover	IntoverD	4,155	18.20517	1.60876	12.90812	24.24381
Herfindahl-Hirschman Index (HHI)	hhi	4,155	0.0359733	0.0851822	0.0012157	0.8505268
Number of highly educated R&D personnel	phd_ma	4,155	7.308063	47.29223	0	1473
Industrial production index by manufacturing industry	ipicsec	4,155	152.7924	38.06822	92.82554	265.6468

Note: Label of variables are explained in Appendix 4.

Appendix 7: Product Innovation-R&D Expenditure (PDRE) Model in Detail

PDRE Product Innovation R&D Expenditure	PDRE1. Total R&D expenditure $Prob(Y_{it} = 1 X_{it}) = \phi[\beta_0 + \beta_1(lntrdexpD) + \beta_2(rdpersinty) + \beta_3(lntoverD) + \beta_4(hhi) + \beta_5(phd\_ma) + \beta_6(ipicsec) + \varepsilon_{it}]$ PDRE2. Internal R&D expenditure $Prob(Y_{it} = 1 X_{it}) = \phi[\beta_0 + \beta_1(lnintrdexpD) + \beta_2(rdpersinty) + \beta_3(lntoverD) + \beta_4(hhi) + \beta_5(phd\_ma) + \beta_6(ipicsec) + \varepsilon_{it}]$ PDRE3. External R&D expenditure $Prob(Y_{it} = 1 X_{it}) = \phi[\beta_0 + \beta_1(IntextrdexpD) + \beta_2(rdpersinty) + \beta_3(lntoverD) + \beta_4(hhi) + \beta_5(phd\_ma) + \beta_6(ipicsec) + \varepsilon_{it}]$ PDRE4. External-domestic R&D expenditure $Prob(Y_{it} = 1 X_{it}) = \phi[\beta_0 + \beta_1(IntextrdexpdomD) + \beta_2(rdpersinty) + \beta_3(lntoverD) + \beta_4(hhi) + \beta_5(phd\_ma) + \beta_6(ipicsec) + \varepsilon_{it}]$ PDRE5. External-foreign R&D expenditure $Prob(Y_{it} = 1 X_{it}) = \phi[\beta_0 + \beta_1(IntextrdexpforD) + \beta_2(rdpersinty) + \beta_3(lntoverD) + \beta_4(hhi) + \beta_5(phd\_ma) + \beta_6(ipicsec) + \varepsilon_{it}]$

Source: Created by Author. *i* stands for firm, *t* stands for time.

Note: Label of variables are explained in Appendix 4 and 6.

Appendix 8: Product Innovation-R&D Intensity (PDRI) Model in Detail

PDRI Product Innovation R&D Intensity	PDRI1. Total R&D intensity $Prob(Y_{it} = 1 X_{it}) = \phi[\beta_0 + \beta_1(totrdint) + \beta_2(rdpersinty) + \beta_3(lntoverD) + \beta_4(hhi) + \beta_5(phd\_ma) + \beta_6(ipicsec) + \varepsilon_{it}]$ PDRI2. Internal R&D intensity $Prob(Y_{it} = 1 X_{it}) = \phi[\beta_0 + \beta_1(intrdint) + \beta_2(rdpersinty) + \beta_3(lntoverD) + \beta_4(hhi) + \beta_5(phd\_ma) + \beta_6(ipicsec) + \varepsilon_{it}]$ PDRI3. External R&D intensity $Prob(Y_{it} = 1 X_{it}) = \phi[\beta_0 + \beta_1(extrdint) + \beta_2(rdpersinty) + \beta_3(lntoverD) + \beta_4(hhi) + \beta_5(phd\_ma) + \beta_6(ipicsec) + \varepsilon_{it}]$ PDRI4. External-domestic R&D intensity $Prob(Y_{it} = 1 X_{it}) = \phi[\beta_0 + \beta_1(extdomrdint) + \beta_2(rdpersinty) + \beta_3(lntoverD) + \beta_4(hhi) + \beta_5(phd\_ma) + \beta_6(ipicsec) + \varepsilon_{it}]$ PDRI5. External-foreign R&D intensity $Prob(Y_{it} = 1 X_{it}) = \phi[\beta_0 + \beta_1(extfrgrdint) + \beta_2(rdpersinty) + \beta_3(lntoverD) + \beta_4(hhi) + \beta_5(phd\_ma) + \beta_6(ipicsec) + \varepsilon_{it}]$

Source: Created by Author. *i* stands for firm, *t* stands for time.

Note: Label of variables are explained in Appendix 4 and 6.

Appendix 9: Process Innovation-R&D Expenditure (PCRE) Model in Detail

PCRE Process Innovation R&D Expenditure	PCRE1. Total R&D expenditure $Prob(Y_{it} = 1 X_{it}) = \phi[\beta_0 + \beta_1(lntrdexpD) + \beta_2(rdpersinty) + \beta_3(lntoverD) + \beta_4(hhi) + \beta_5(phd\_ma) + \beta_6(ipicsec) + \varepsilon_{it}]$ PCRE2. Internal R&D expenditure $Prob(Y_{it} = 1 X_{it}) = \phi[\beta_0 + \beta_1(lnintrdexpD) + \beta_2(rdpersinty) + \beta_3(lntoverD) + \beta_4(hhi) + \beta_5(phd\_ma) + \beta_6(ipicsec) + \varepsilon_{it}]$ PCRE3. External R&D expenditure $Prob(Y_{it} = 1 X_{it}) = \phi[\beta_0 + \beta_1(IntextrdexpD) + \beta_2(rdpersinty) + \beta_3(lntoverD) + \beta_4(hhi) + \beta_5(phd\_ma) + \beta_6(ipicsec) + \varepsilon_{it}]$ PCRE4. External-domestic R&D expenditure $Prob(Y_{it} = 1 X_{it}) = \phi[\beta_0 + \beta_1(IntextrdexpdomD) + \beta_2(rdpersinty) + \beta_3(lntoverD) + \beta_4(hhi) + \beta_5(phd\_ma) + \beta_6(ipicsec) + \varepsilon_{it}]$ PCRE5. External-foreign R&D expenditure $Prob(Y_{it} = 1 X_{it}) = \phi[\beta_0 + \beta_1(IntextrdexpforD) + \beta_2(rdpersinty) + \beta_3(lntoverD) + \beta_4(hhi) + \beta_5(phd\_ma) + \beta_6(ipicsec) + \varepsilon_{it}]$

Source: Created by Author. *i* stands for firm, *t* stands for time.

Note: Label of variables are explained in Appendix 4 and 6.

Appendix 10: Process Innovation-R&D Intensity (PCRI) Model in Detail

PCRI Process Innovation R&D Intensity	PCRI1. Total R&D intensity $Prob(Y_{it} = 1 X_{it}) = \phi[\beta_0 + \beta_1(totrdint) + \beta_2(rdpersinty) + \beta_3(lntoverD) + \beta_4(hhi) + \beta_5(phd\_ma) + \beta_6(ipicsec) + \varepsilon_{it}]$ PCRI2. Internal R&D intensity $Prob(Y_{it} = 1 X_{it}) = \phi[\beta_0 + \beta_1(intrdint) + \beta_2(rdpersinty) + \beta_3(lntoverD) + \beta_4(hhi) + \beta_5(phd\_ma) + \beta_6(ipicsec) + \varepsilon_{it}]$ PCRI3. External R&D intensity $Prob(Y_{it} = 1 X_{it}) = \phi[\beta_0 + \beta_1(extrdint) + \beta_2(rdpersinty) + \beta_3(lntoverD) + \beta_4(hhi) + \beta_5(phd\_ma) + \beta_6(ipicsec) + \varepsilon_{it}]$ PCRI4. External-domestic R&D intensity $Prob(Y_{it} = 1 X_{it}) = \phi[\beta_0 + \beta_1(extdomrdint) + \beta_2(rdpersinty) + \beta_3(lntoverD) + \beta_4(hhi) + \beta_5(phd\_ma) + \beta_6(ipicsec) + \varepsilon_{it}]$ PCRI5. External-foreign R&D intensity $Prob(Y_{it} = 1 X_{it}) = \phi[\beta_0 + \beta_1(extfrgrdint) + \beta_2(rdpersinty) + \beta_3(lntoverD) + \beta_4(hhi) + \beta_5(phd\_ma) + \beta_6(ipicsec) + \varepsilon_{it}]$

Source: Created by Author. *i* stands for firm, *t* stands for time.

Note: Label of variables are explained in Appendix 4 and 6.

Appendix 11: Summary Table for R&D Expenditure and R&D Intensity in Product Innovation, by Section C and Division

H	H1	H1a	H1b	H1c	H1d	H2	H2a	H2b	H2c	H2d
Model & Sector	PDRE1	PDRE2	PDRE3	PDRE4	PDRE5	PDR1	PDR2	PDR3	PDR4	PDR5
C	+ *** 0.71	+ *** 4.24	+ ** 0.32	+ * 0.28	X	+ * 0.27	X	+ *** 0.34	+ *** 0.27	+ ** 1.61
10	X	X	X	X	X	X	X	X	X	+ ** 144.2
13	+ ** 4.53	+ ** 4.53	W	W	W	+ *** 4.86	+ *** 4.69	+ *** 103.6	+ ** 75.5	+ *** 153.5
20	X	X	- ** 1.27	- * 1.05	- ** 2.32	X	X	X	X	X
21	X	X	+ ** 1.83	+ * 1.53	X	X	X	+ * 1.50	+ ** 1.63	+ * 5.97
22	X	X	+ * 0.73	X	+ * 1.12	X	X	X	X	X
23	+ *** 13.09	+ *** 11.6	X	X	X	W	W	W	+ ** 42.21	X
24	+ *** 7.59	+ *** 7.90	X	X	X	+ ** 8.37	+ ** 8.71	X	- ** 23.35	+ *** 13.27
25	+ ** 4.85	+ ** 4.50	X	+ * 1.16	X	+ * 0.84	+ * 0.78	+ ** 71.8	+ * 230.6	W
26	+ * 3.48	+ * 3.51	X	X	+ *** 1.1	X	X	X	X	+ *** 49.07
27	X	+ * 3.93	X	X	X	X	X	X	X	X
28	W	W	W	W	W	W	W	+ *** 4.05	+ *** 4.63	+ *** 0.84
29	+ * 5.82	+ * 5.88	+ * 0.78	X	+ * 2	X	X	X	X	+ * 209.9

Note: Significance level: * p<0.1 ** p<0.05 *** p<0.01.

“+” and “-” stand for positive and negative, respectively. “x” means that independent variable is not statistically significant. “w” means that the Wald test of the model is not statistically significant. Numbers are average marginal effects.

Appendix 12: Summary Table for R&D Expenditure and R&D Intensity in Process Innovation, by Section C and Division

H	H3	H3a	H3b	H3c	H3d	H4	H4a	H4b	H4c	H4d
Model & Sector	PCRE1	PCRE2	PCRE3	PCRE4	PCRE5	PCRI1	PCRI2	PCRI3	PCRI4	PCRI5
C	+ *** 2.98	+ *** 3	+ ** 0.04	X	+ ** 0.77	X	X	+ *** 0.63	+ *** 0.45	+ ** 8.47
10	w	w	X	X	w	w	w	w	- *** 56.19	X
13	X	X	X	X	X	X	X	X	+ ** 40.14	+ * 179.4
20	X	X	X	X	X	C	X	X	X	+ ** 40.4
21	+ * 3.99	X	+ * 1.28	+ * 1.01	X	+ *** 2.27	+ *** 2.27	+ *** 3.97	+ *** 3.58	+ *** 2.50
22	X	X	X	X	X	X	X	X	X	X
23	+ *** 10.13	+ ** 8.31	w	w	w	w	w	w	w	C
24	+ ** 6.65	+ * 6.38	w	w	w	w	w	+ ** 32.41	+ * 34.43	+ *** 26.56
25	X	X	X	w	X	w	w	w	w	- *** 83.79
26	- ** 6.42	- ** 6.85	X	X	X	X	X	+ *** 0.24	+ *** 0.24	X
27	X	X	X	X	w	w	w	w	X	w
28	X	X	X	X	X	X	X	X	X	+ *** 1.38
29	+ *** 6.21	+ ** 6.18	+ * 0.72	+ * 0.73	X	X	X	+ *** 8.81	+ *** 7.43	X

Note: Significance level: * p<0.1 ** p<0.05 *** p<0.01.

“+” and “-” stand for positive and negative, respectively. “x” means that independent variable is not statistically significant. “w” means that the Wald test of the model is not statistically significant. “c” stands for nonachievements of convergence. Numbers are average marginal effects.

Appendix 13: Summary Table for R&D Expenditure and R&D Intensity in Product Innovation, by Technology Intensity Classification

H	<i>H1</i>	<i>H1a</i>	<i>H1b</i>	<i>H1c</i>	<i>H1d</i>	<i>H2</i>	<i>H2a</i>	<i>H2b</i>	<i>H2c</i>	<i>H2d</i>
Model & Class	PDR1	PDR2	PDR3	PDR4	PDR5	PDR1	PDR2	PDR3	PDR4	PDR5
HT	x	x	+ * 0.86	x	x	x	x	x	x	x
MHT	+ ** 3.1	+ ** 3.38	x	x	x	x	x	x	x	x
MLT	+ *** 6.96	+ *** 6.68	w	w	w	+ *** 1.06	+ *** 0.99	+ *** 6.14	+ *** 0.4	w
LT	+ *** 3.28	+ ** 3.2	+ ** 0.8	x	+ *** 1.36	+ ** 0.84	+ * 0.92	x	x	+ *** 243.5

Note: Significance level: * p<0.1 ** p<0.05 *** p<0.01.

“+” and “-” stand for positive and negative, respectively. “x” means that independent variable is not statistically significant. “w” means that the Wald test of the model is not statistically significant. Numbers are average marginal effects.

Appendix 14: Summary Table for R&D Expenditure and R&D Intensity in Process Innovation, by Technology Intensity Classification

H	<i>H1</i>	<i>H1a</i>	<i>H1b</i>	<i>H1c</i>	<i>H1d</i>	<i>H2</i>	<i>H2a</i>	<i>H2b</i>	<i>H2c</i>	<i>H2d</i>
Model & Class	PCRE1	PCRE2	PCRE3	PCRE4	PCRE5	PCR11	PCR12	PCR13	PCR14	PCR15
HT	x	x	x	x	x	+ ** 0.51	x	+ *** 1.1	+ *** 1.06	+ *** 6.24
MHT	+ ** 2.75	+ ** 2.9	x	x	x	x	x	x	x	+ * 1.46
MLT	+ *** 4.59	+ *** 4.41	x	x	x	x	x	+ *** 0.52	+ *** 0.46	x
LT	+ * 2.58	+ ** 2.78	x	x	+ *** 1.25	x	x	+ *** 1.96	+ *** 2.21	x

Note: Significance level: * p<0.1 ** p<0.05 *** p<0.01.

“+” and “-” stand for positive and negative, respectively. “x” means that independent variable is not statistically significant. “w” means that the Wald test of the model is not statistically significant. Numbers are average marginal effects.

Appendix 15: Summary Table for R&D Expenditure and R&D Intensity in Product Innovation, by Education Intensity Classification

H	<i>H1</i>	<i>H1a</i>	<i>H1b</i>	<i>H1c</i>	<i>H1d</i>	<i>H2</i>	<i>H2a</i>	<i>H2b</i>	<i>H2c</i>	<i>H2d</i>
Model & Class	PDI1	PDI2	PDI3	PDI4	PDI5	PDI1	PDI2	PDI3	PDI4	PDI5
HEI	+ ** 3.56	+ ** 3.88	x	x	x	x	x	x	x	x
MHEI	+ * 2.46	+ * 2.35	x	x	x	x	x	x	x	x
MLEI	+ *** 5.17	+ *** 5.02	+ * 0.46	x	+ ** 1.26	x	x	+ * 19.02	x	+ ** 188.5
LEI	w	w	w	w	+ *** 2.55	w	w	w	w	+ *** 2594.5

Note: Significance level: * p<0.1 ** p<0.05 *** p<0.01.

“+” and “-” stand for positive and negative, respectively. “x” means that independent variable is not statistically significant. “w” means that the Wald test of the model is not statistically significant. Numbers are average marginal effects.

Appendix 16: Summary Table for R&D Expenditure and R&D Intensity in Process Innovation, by Education Intensity Classification

H	<i>H1</i>	<i>H1a</i>	<i>H1b</i>	<i>H1c</i>	<i>H1d</i>	<i>H2</i>	<i>H2a</i>	<i>H2b</i>	<i>H2c</i>	<i>H2d</i>
Model & Class	PCRE1	PCRE2	PCRE3	PCRE4	PCRE5	PCR11	PCR12	PCR13	PCR14	PCR15
HEI	x	x	x	x	x	x	x	+ *** 0.23	+ *** 0.22	x
MHEI	+ * 2.11	+ * 2.13	x	x	x	x	x	x	x	+ *** 5.93
MLEI	+ ** 2.78	+ ** 2.78	x	x	x	x	x	x	x	x
LEI	+ ** 5.32	+ ** 5.52	x	x	+ *** 3.61	+ ** 0.52	+ * 0.45	x	+ *** 3.72	+ *** 2889.6

Note: Significance level: * p<0.1 ** p<0.05 *** p<0.01.
“+” and “-” stand for positive and negative, respectively. “x” means that independent variable is not statistically significant. “w” means that the Wald test of the model is not statistically significant. Numbers are average marginal effects.

Appendix 17: Summary Table for R&D Expenditure and R&D Intensity in Product Innovation, by Firm Size Classification

H	<i>H1</i>	<i>H1a</i>	<i>H1b</i>	<i>H1c</i>	<i>H1d</i>	<i>H2</i>	<i>H2a</i>	<i>H2b</i>	<i>H2c</i>	<i>H2d</i>
Model & Class	PDRE1	PDRE2	PDRE3	PDRE4	PDRE5	PDR1	PDR2	PDR3	PDR4	PDR5
Small	w	w	w	w	w	w	w	+	+	+
								***	**	***
								0.15	0.14	14.92
Medium	+	+				+	+	+	+	+
	***	***	x	x	x	***	***	***	**	***
	3.61	3.53				0.63	0.58	1.01	0.901	68.95
Large	+	+	+		+					
	***	***	*	x	*	x	x	x	x	x
	4.56	4.57	0.35		0.73					

Note: Significance level: * p<0.1 ** p<0.05 *** p<0.01.

“+” and “-” stand for positive and negative, respectively. “x” means that independent variable is not statistically significant. “w” means that the Wald test of the model is not statistically significant. Numbers are average marginal effects.

Appendix 18: Summary Table for R&D Expenditure and R&D Intensity in Process Innovation, by Firm Size Classification

H	<i>H1</i>	<i>H1a</i>	<i>H1b</i>	<i>H1c</i>	<i>H1d</i>	<i>H2</i>	<i>H2a</i>	<i>H2b</i>	<i>H2c</i>	<i>H2d</i>
Model & Class	PCRE1	PCRE2	PCRE3	PCRE4	PCRE5	PCRI1	PCRI2	PCRI3	PCRI4	PCRI5
Small	x	x	x	x	+ *** 0.61	x	x	+ *** 0.17	+ *** 0.16	+ *** 17.86
Medium	+ * 2.02	x	x	x	+ ** 1.03	+ * 0.15	+ * 0.13	+ *** 0.81	+ *** 0.79	+ * 166.75
Large	+ *** 3.08	+ *** 3.12	x	x	x	x	x	x	x	x

Note: Significance level: * p<0.1 ** p<0.05 *** p<0.01.

“+” and “-” stand for positive and negative. “x” means that independent variable is not statistically significant. “w” means that the Wald test of the model is not statistically significant. Numbers are average marginal effects.

Appendix 19: GERD as A Percentage of GDP by Country, 1981-2020

Country /	Year	1981	1982	1983	1984	1985	1986	1987	1988	1989
Australia		0.90	..	..	1.02	..	1.18	1.14	1.16	..
Austria		1.09 ^(e)	1.14 ^(e)	1.14 ^(e)	1.19	1.20 ^(e)	1.24 ^(e)	1.24 ^(e)	1.28	1.30
Belgium		..	..	1.50	1.51	1.56	1.56 ^(e)	1.57 ^(e)	1.53 ^(be)	1.58
Canada		1.20	1.34	1.31	1.34	1.38	1.42	1.37 ^(b)	1.35	1.42
Chile		..	..	..	..	..	..	..	..	..
Colombia		..	..	..	..	..	..	..	..	..
Czech Republic		..	..	..	..	..	..	..	..	..
Denmark		1.01	1.05	1.10	1.13	1.16	1.24	1.33	1.40	1.45
Estonia		..	..	..	..	..	..	..	..	..
Finland		1.15	..	1.30	1.43 ^(e)	1.52	1.60	1.69 ^(e)	1.72	1.75
France		1.87	1.95	1.98	2.07	2.13	2.12	2.16	2.15	2.19
Germany		2.35 ^(e)	2.42	2.41 ^(e)	2.43	2.59 ^(e)	2.63	2.73 ^(e)	2.73	2.71
Greece		0.15	..	..	..	..	0.23	..	0.26 ^(b)	0.32
Hungary		..	..	..	..	..	..	..	..	..
Iceland		0.63	..	0.67	0.71	0.72	0.71	0.75	..	0.97
Ireland		0.65	0.64	0.62	0.68	0.73	0.80	0.79	0.76 ^(e)	0.77
Israel		..	..	..	..	..	..	..	..	..
Italy		^(d) 0.83 ^(d)	^(d) 0.85 ^(d)	^(d) 0.90 ^(d)	^(d) 0.95 ^(d)	^(d) 1.06 ^(d)	^(d) 1.07 ^(d)	^(d) 1.12 ^(d)	^(d) 1.14 ^(d)	^(d) 1.16
Japan		^(e) 2.00 ^(e)	^(e) 2.08 ^(e)	^(e) 2.19 ^(e)	^(e) 2.28 ^(e)	^(e) 2.43 ^(e)	^(e) 2.40 ^(e)	^(e) 2.45 ^(e)	^(e) 2.48 ^(e)	^(e) 2.58
Korea		..	..	..	..	..	..	..	..	..
Lithuania		..	..	..	..	..	..	..	..	..
Latvia		..	..	..	..	..	..	..	..	..
Luxembourg		..	..	..	..	..	..	..	..	..
Mexico		..	..	..	..	..	..	..	..	..
Netherlands		1.62 ^(b)	1.72	1.76	1.70	1.83	1.94	2.02	1.96	1.88
New Zealand		^(e) 0.97	.. ^(e)	0.87	..	..	..	..	..	0.83
Norway		1.15 ^(e)	1.22	1.27 ^(be)	1.35	1.44	..	1.61	..	1.63
Poland		..	..	..	..	..	..	..	..	..
Portugal		..	0.27 ^(e)	0.30	0.31 ^(e)	0.34	0.34 ^(e)	0.37	0.37 ^(e)	0.43
Slovak Republic		..	..	..	..	..	..	..	..	..
Slovenia		..	..	..	..	..	..	..	..	..
Spain		0.39	0.45	0.44	0.46	0.51	0.56	0.59	0.66	0.69
Sweden		^(e) 2.03	.. ^(e)	2.26	.. ^(e)	2.55	.. ^(e)	2.63	.. ^(e)	2.58
Switzerland		^(e) 1.91	.. ^(bd)	1.93	..	.. ^(b)	2.45	..	.. ^(b)	2.43
Türkiye		..	..	..	..	..	..	..	..	..
United Kingdom		2.24	..	2.06	.. ^(b)	2.09	2.10	2.02	1.96	1.95
United States		^(d) 2.27 ^(d)	^(d) 2.43 ^(d)	^(d) 2.49 ^(d)	^(d) 2.55 ^(d)	^(d) 2.66 ^(d)	^(d) 2.63 ^(d)	^(d) 2.61 ^(d)	^(d) 2.56 ^(d)	^(d) 2.52
EU-27 countries (from 01/02/2020)		..	..	..	..	..	..	..	..	..
OECD - Total		..	..	..	..	..	..	..	..	..
Non-OECD Economies	Argentina	..	..	..	..	..	..	..	..	..
	China (People's Republic of)	..	..	..	..	..	..	..	..	..
	Romania	..	..	..	..	..	..	..	..	..
	Russia	..	..	..	..	..	..	..	..	1.77
	Singapore	..	..	..	..	..	..	..	..	..
	South Africa	..	..	0.79	..	0.82	..	0.74	..	0.68
	Chinese Taipei	..	..	..	..	..	..	..	..	..

Source: OECD Stat. [Data extracted on 20 Mar 2023 17:46 UTC \(GMT\) from OECD.Stat.](#)

e: Estimated value, b: Time series break, p: Provisional value, d: Definition differs, v: The sum of the breakdown does not add to the total, m: Underestimated or based on underestimated data.

Appendix 19: Continue

Country / Year		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Australia		1.26	..	1.46	..	1.51	..	1.58	..	1.44	..
Austria	(e)	1.35	(e) 1.43	(e) 1.41	1.43	(e) 1.51	(e) 1.53	(e) 1.58	(e) 1.65	1.73	(e) 1.85
Belgium		..	(e) 1.56	..	(b) 1.64	1.63	1.65	1.74	1.81	1.84	1.91
Canada		1.48	1.53	1.58	1.63	1.68	1.65	1.61	1.61	1.71	1.75
Chile		..	..	..	..	..	..	..	..	..	..
Colombia		..	..	..	..	..	..	..	..	..	..
Czech Republic		..	..	..	..	..	0.88	0.89	0.99	1.06	1.05
Denmark		1.52	1.58	1.61	1.69	..	1.79	(e) 1.81	1.89	(e) 2.01	2.13
Estonia		..	..	..	..	..	..	..	..	0.57	0.68
Finland	(e)	1.82	(b) 1.97	(e) 2.06	2.10	2.21	2.20	(e) 2.45	2.62	2.78	3.06
France		2.27	2.28	2.28	2.32	2.27	2.24	2.22	(b) 2.15	2.09	2.11
Germany	(e)	2.61	(b) 2.39	(e) 2.27	(d) 2.21	(d) 2.13	2.14	(e) 2.14	2.19	(e) 2.22	2.35
Greece		..	0.31	..	0.40	..	(b) 0.42	..	0.43	..	0.57
Hungary		..	1.03	(d) 1.01	(d) 0.94	(bd) 0.86	(d) 0.71	(d) 0.63	(d) 0.70	(d) 0.66	(d) 0.67
Iceland		0.96	1.13	1.30	1.31	1.35	1.51	..	1.80	(e) 1.95	2.24
Ireland	(e)	0.79	(e) 0.89	(e) 0.99	(e) 1.12	(e) 1.22	(e) 1.23	(e) 1.27	(e) 1.24	(e) 1.21	(e) 1.15
Israel		..	2.21	(d) 2.27	(d) 2.37	(d) 2.42	(d) 2.43	(d) 2.59	(d) 2.81	(d) 2.92	(d) 3.33
Italy	(d)	1.20	(b) 1.14	1.10	1.05	0.98	0.93	0.95	(b) 0.99	1.00	0.98
Japan	(e)	2.66	(e) 2.63	(e) 2.58	(e) 2.52	(e) 2.47	(e) 2.56	(b) 2.64	2.72	2.83	2.85
Korea		..	(d) 1.71	(d) 1.80	(d) 1.95	(d) 2.12	(d) 2.16	(d) 2.22	(d) 2.25	(d) 2.11	(d) 2.02
Lithuania		..	..	..	..	..	0.43	(b) 0.49	0.54	0.54	0.50
Latvia		..	..	..	..	..	0.43	0.40	0.37	0.38	0.35
Luxembourg		..	..	..	..	..	..	..	..	..	..
Mexico		..	..	..	(e) 0.18	0.23	0.25	0.25	0.28	0.30	0.34
Netherlands	(b)	1.92	1.82	1.75	1.77	(b) 1.81	1.82	(b) 1.84	1.84	1.74	(b) 1.82
New Zealand		0.95	0.94	(b) 0.96	0.98	..	0.92	..	1.06	..	0.96
Norway		..	1.60	..	1.67	..	(b) 1.65	..	1.59	..	1.61
Poland		0.86	0.72	0.74	0.74	(d) 0.68	(b) 0.62	0.64	0.64	0.66	0.68
Portugal		0.46	(e) 0.51	0.55	(e) 0.55	(e) 0.53	0.52	(e) 0.55	0.56	(e) 0.62	0.68
Slovak Republic	(d)	1.61	(d) 2.07	(bd) 1.73	(d) 1.33	(bd) 0.87	(d) 0.90	(d) 0.89	(b) 1.05	0.77	0.64
Slovenia		..	..	..	1.53	1.68	(e) 1.49	1.26	1.25	1.31	1.34
Spain		0.78	0.80	(b) 0.84	0.83	(e) 0.77	0.77	(e) 0.79	0.78	(e) 0.85	0.84
Sweden		..	(e) 2.52	..	(be) 2.96	..	(be) 3.10	..	(e) 3.27	..	(e) 3.38
Switzerland		..	..	2.31	..	..	..	2.37	..	..	..
Türkiye		0.24	0.38	0.36	0.32	0.26	0.28	0.33	0.36	0.36	0.46
United Kingdom		1.95	1.87	(b) 1.84	1.86	1.84	1.64	1.57	1.54	1.55	1.62
United States	(d)	2.56	(d) 2.62	(d) 2.54	(d) 2.42	(d) 2.33	(d) 2.41	2.45	(d) 2.48	(bd) 2.50	(d) 2.54
EU-27 countries (from 01/02/2020)		..	(e) 1.65	(e) 1.63	(e) 1.62	(e) 1.57	(e) 1.56	(e) 1.57	(e) 1.59	(e) 1.60	(e) 1.65
OECD - Total		..	(e) 2.02	(e) 1.98	(e) 1.94	(e) 1.89	(be) 1.92	(e) 1.94	(e) 1.96	(e) 1.99	(e) 2.04
Non-OECD Economies	Argentina	..	..	..	..	..	..	0.37	0.38	0.37	0.41
	China (People's Republic of)	..	(m) 0.72	(m) 0.73	(m) 0.70	(m) 0.63	(m) 0.57	(m) 0.56	(m) 0.64	(m) 0.65	(m) 0.75
	Romania	..	(de) 0.74	(bde) 0.80	(die) 0.87	(die) 0.73	(b) 0.76	0.67	0.57	0.50	0.40
	Russia	1.89	1.33	0.69	0.72	0.79	0.79	0.90	0.97	0.89	0.93
	Singapore	..	..	..	..	1.04	1.10	1.32	1.42	1.74	1.82
	South Africa	..	0.81	..	0.59	..	..	..	0.58	..	..
	Chinese Taipei	..	..	..	..	..	(d) 1.69	(d) 1.72	(d) 1.80	(d) 1.88	(d) 1.94

Source: OECD Stat. [Data extracted on 20 Mar 2023 17:46 UTC \(GMT\) from OECD.Stat.](#)

e: Estimated value, b: Time series break, p: Provisional value, d: Definition differs, v: The sum of the breakdown does not add to the total, m: Underestimated or based on underestimated data.

Appendix 19: Continue

Country /	Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	
Australia		1.47	..	1.65	..	1.73	..	2.00	..	2.25	..	
Austria	(e)	1.89	(e) 1.99	2.07	(e) 2.17	2.17	(e) 2.37	2.36	2.42	(e) 2.57	2.60	
Belgium		1.94	2.03	1.90	1.84	1.82	1.79	1.82	1.85	1.94	2.00	
Canada		1.86	2.02	1.97	1.97	2.00	1.97	1.94	1.90	1.86	1.92	
Chile		..	..	..	..	..	..	..	0.31	0.37	(b) 0.35	
Colombia	(e)	0.14	(e) 0.14	(e) 0.16	0.18	0.17	0.17	0.16	0.18	0.20	0.19	
Czech Republic		1.11	1.10	1.10	1.14	1.14	1.16	1.23	1.30	1.23	1.29	
Denmark		..	2.32	2.44	2.51	2.42	2.39	2.40	(b) 2.52	2.77	3.06	
Estonia		0.60	0.70	0.71	0.76	0.85	0.92	1.11	1.06	1.25	1.40	
Finland		3.24	3.19	3.25	3.30	3.31	3.32	3.33	3.34	3.54	3.73	
France	(b)	2.09	2.14	2.17	2.12	(b) 2.09	2.05	2.05	2.02	2.06	2.21	
Germany		2.41	2.40	2.44	2.47	2.44	2.44	2.47	2.46	2.62	2.74	
Greece		..	0.56	..	0.55	(e) 0.53	0.58	(e) 0.56	(e) 0.58	(be) 0.66	(e) 0.63	
Hungary	(d)	0.79	(d) 0.91	(d) 0.98	(d) 0.92	(b) 0.86	0.92	0.98	0.95	0.98	1.13	
Iceland	(e)	2.57	2.84	(e) 2.82	2.71	..	2.68	2.85	2.53	2.46	2.60	
Ireland	(e)	1.08	1.05	1.06	1.12	1.18	1.19	1.20	1.23	1.39	(e) 1.61	
Israel	(bd)	3.93	(d) 4.18	(d) 4.13	(d) 3.89	(d) 3.87	(d) 4.04	(d) 4.14	(d) 4.42	(d) 4.33	(d) 4.12	
Italy		1.00	1.04	1.08	1.06	1.05	1.04	1.08	1.13	1.16	1.22	
Japan		2.86	2.92	2.97	2.99	2.98	3.13	3.23	3.29	(b) 3.29	3.20	
Korea	(d)	2.13	(d) 2.28	(d) 2.21	(d) 2.28	(d) 2.44	(d) 2.52	(d) 2.72	(b) 2.87	2.99	3.15	
Lithuania		0.59	0.67	0.66	0.66	0.75	0.75	0.79	0.80	0.79	0.83	
Latvia		0.43	0.40	0.41	0.36	0.40	0.53	0.65	0.55	0.58	0.45	
Luxembourg		1.58	..	..	1.62	1.59	1.56	1.65	(e) 1.57	1.55	1.59	
Mexico		0.31	0.32	0.35	0.39	(b) 0.39	0.40	0.37	0.40	0.44	0.48	
Netherlands		1.79	1.80	1.75	1.78	1.79	1.77	1.74	1.67	1.62	1.67	
New Zealand		..	(b) 1.10	..	1.15	..	1.12	..	1.16	..	1.25	
Norway		..	1.56	1.63	1.68	1.54	1.48	1.46	1.56	1.55	1.72	
Poland		0.64	0.62	0.56	0.54	0.55	0.56	0.55	0.56	0.60	0.66	
Portugal	(e)	0.72	0.76	(e) 0.72	0.70	(e) 0.73	0.76	(e) 0.95	1.12	(b) 1.44	1.58	
Slovak Republic		0.64	0.62	0.56	0.56	0.50	0.49	0.47	0.45	0.46	0.47	
Slovenia		1.36	1.47	1.44	1.25	1.37	1.42	1.54	1.43	(b) 1.63	1.81	
Spain		0.88	0.89	0.96	1.02	1.04	1.10	1.18	1.24	(b) 1.32	1.36	
Sweden		..	(e) 3.87	..	(e) 3.58	(e) 3.36	(b) 3.36	(e) 3.47	3.23	(e) 3.47	3.40	
Switzerland		2.26	..	..	..	2.60	..	..	..	2.64	..	
Türkiye		0.47	0.52	0.51	0.47	0.50	0.56	0.55	0.69	0.69	0.80	
United Kingdom		1.61	1.60	1.62	1.58	1.53	1.55	1.57	1.61	(e) 1.60	(e) 1.66	
United States	(d)	2.62	(d) 2.64	(d) 2.55	(bd) 2.55	(d) 2.49	(d) 2.50	(d) 2.55	(d) 2.62	(d) 2.74	(d) 2.79	
EU-27 countries (from 01/02/2020)	(e)	1.68	(e) 1.70	(e) 1.71	(e) 1.70	(e) 1.68	(e) 1.68	(e) 1.70	(e) 1.70	(e) 1.78	(e) 1.86	
OECD - Total	(e)	2.08	(e) 2.12	(e) 2.09	(e) 2.10	(e) 2.07	(e) 2.10	(e) 2.13	(e) 2.17	(e) 2.24	(e) 2.28	
Non-OECD Economies	Argentina		0.39	0.38	0.35	0.37	0.40	0.42	0.45	0.46	0.47	(bp) 0.59
	China (People's Republic of)	(b)	0.89	0.94	1.06	1.12	1.21	1.31	1.37	1.37	1.45	(b) 1.66
	Romania		0.37	0.39	0.38	0.40	0.39	0.41	0.46	0.51	0.55	0.44
	Russia		0.98	1.10	1.16	1.20	1.07	0.99	1.00	1.04	0.97	1.17
	Singapore		1.82	2.01	2.03	2.00	2.08	2.15	2.12	2.32	2.60	2.13
	South Africa		..	(m) 0.72	..	0.76	0.81	0.86	0.90	0.88	0.89	0.84
	Chinese Taipei	(d)	1.91	(d) 2.03	(b) 2.11	(b) 2.22	2.27	2.33	2.44	2.48	2.67	2.84

Source: OECD Stat. [Data extracted on 20 Mar 2023 17:46 UTC \(GMT\) from OECD.Stat.](#)

e: Estimated value, b: Time series break, p: Provisional value, d: Definition differs, v: The sum of the breakdown does not add to the total, m: Underestimated or based on underestimated data.

Appendix 19: Continue

Country /	Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Australia	(e)	2.18	(e) 2.11	..	(e) 2.09	..	(e) 1.88	..	(e) 1.79	..	(e) 1.80	..
Austria	(e)	2.73	2.67	(e) 2.91	2.95	(e) 3.08	3.05	(e) 3.12	3.06	(e) 3.09	3.13	(e) 3.22
Belgium		2.06	2.17	2.28	2.33	2.37	2.43	2.52	2.67	2.86	3.16	(e) 3.38
Canada		1.83	1.79	(b) 1.77	1.71	(b) 1.71	1.69	1.73	1.69	1.74	1.75	(p) 1.84
Chile		0.33	0.35	0.36	0.39	(b) 0.38	0.38	(b) 0.37	0.36	(e) 0.37	(e) 0.34	(e) 0.34
Colombia		0.19	0.20	0.22	0.26	0.30	0.37	0.27	0.26	0.31	(e) 0.32	(e) 0.29
Czech Republic		1.33	1.54	1.77	1.88	1.96	1.92	1.67	1.77	1.90	1.93	1.99
Denmark		2.92	2.94	2.98	2.97	2.91	3.05	3.09	2.93	2.97	2.90	2.97
Estonia		1.58	2.31	2.12	1.72	1.43	1.47	1.24	1.28	1.41	1.63	1.75
Finland		3.71	3.62	3.40	3.27	3.15	2.87	2.72	2.73	2.76	2.80	2.91
France	(b)	2.18	2.19	2.23	2.24	(b) 2.28	2.23	2.22	2.20	2.20	2.19	(ep) 2.35
Germany		2.73	2.81	2.88	2.84	2.88	2.93	2.94	3.05	3.11	3.17	(e) 3.13
Greece	(e)	0.60	0.68	0.71	0.81	0.84	0.97	1.01	1.15	1.21	1.28	1.51
Hungary		1.13	1.18	1.25	1.38	1.34	1.34	1.18	1.32	(b) 1.51	1.48	1.60
Iceland		..	(be) 2.40	..	(b) 1.69	(e) 1.94	2.18	(e) 2.11	2.08	(e) 2.00	2.33	2.47
Ireland	(e)	1.59	(e) 1.55	(e) 1.56	(e) 1.57	(e) 1.52	(e) 1.18	(e) 1.18	(e) 1.25	(e) 1.17	(e) 1.23	(e) 1.08
Israel	(d)	3.92	(d) 4.00	(d) 4.14	(d) 4.07	(d) 4.16	(d) 4.26	(d) 4.51	(d) 4.66	(d) 4.80	(de) 5.14	(d) 5.44
Italy		1.22	1.20	1.26	1.30	(e) 1.34	1.34	(b) 1.37	1.37	1.42	1.46	1.51
Japan		3.10	3.21	3.17	(b) 3.28	3.37	3.24	3.11	3.17	(b) 3.22	3.21	3.27
Korea		3.32	3.59	3.85	3.95	4.08	3.98	3.99	4.29	4.52	4.63	4.81
Lithuania		0.78	0.90	0.89	0.95	1.03	1.04	0.84	0.90	0.94	0.99	1.17
Latvia		0.61	0.72	0.66	0.61	0.69	0.62	0.44	0.51	0.64	0.64	0.71
Luxembourg		1.42	1.42	(b) 1.21	1.23	1.22	1.25	1.27	1.24	1.17	1.18	(ep) 1.07
Mexico		0.49	0.47	0.42	0.43	0.44	0.43	0.39	(e) 0.33	(e) 0.31	(e) 0.28	(e) 0.30
Netherlands		1.70	(b) 1.88	(b) 1.92	(b) 2.16	2.17	2.15	2.15	2.18	2.14	2.18	2.32
New Zealand		..	1.23	..	1.15	..	1.23	..	1.35	..	(p) 1.40	..
Norway		1.65	1.63	1.62	1.65	1.72	1.94	2.04	2.10	2.05	2.16	2.28
Poland		0.72	0.75	0.88	0.88	0.94	1.00	0.96	1.03	1.21	1.32	1.39
Portugal		1.54	1.46	1.38	1.32	1.29	1.24	1.28	1.32	1.35	1.40	1.62
Slovak Republic		0.61	0.66	0.80	0.82	0.88	1.16	0.79	0.89	0.84	0.83	0.91
Slovenia		2.05	(b) 2.41	2.56	2.56	2.37	2.20	2.01	1.87	1.95	2.04	2.14
Spain		1.36	1.33	1.30	1.28	1.24	1.22	1.19	1.21	1.24	1.25	1.41
Sweden	(e)	3.17	3.19	(e) 3.23	(e) 3.26	(e) 3.10	(v) 3.22	(e) 3.25	(v) 3.36	(e) 3.32	(v) 3.39	3.49
Switzerland		..	..	2.85	..	..	3.04	..	3.03	..	3.15	..
Türkiye		0.79	0.79	0.83	0.81	0.86	0.88	0.94	0.95	1.03	1.07	1.09
United Kingdom	(e)	1.64	1.64	(e) 1.57	1.61	(e) 1.63	1.63	(e) 1.65	1.66	(e) 1.71	1.71	..
United States	(d)	2.71	(d) 2.74	(d) 2.67	(d) 2.70	(d) 2.72	(bd) 2.79	(bd) 2.85	(d) 2.91	(d) 3.01	(d) 3.18	(p) 3.45
EU-27 countries (from 01/02/2020)	(e)	1.86	(e) 1.91	(e) 1.96	(e) 1.98	(e) 2.00	(e) 2.00	(e) 1.99	(e) 2.03	(e) 2.07	(e) 2.11	(e) 2.19
OECD - Total	(e)	2.24	(e) 2.27	(e) 2.27	(e) 2.29	(e) 2.32	(e) 2.33	(e) 2.33	(e) 2.37	(e) 2.44	(e) 2.52	(e) 2.67
Non-OECD Economies	Argentina	(p) 0.56	(p) 0.57	(p) 0.64	(p) 0.62	(p) 0.59	0.62	0.53	0.56	0.49	0.46	..
	China (People's Republic of)	1.71	1.78	1.91	2.00	2.02	2.06	2.10	2.12	2.14	2.23	2.40
	Romania	0.46	(b) 0.50	0.49	0.39	0.38	0.49	0.48	0.50	0.50	0.48	0.47
	Russia	1.05	1.02	1.03	1.03	1.07	1.10	1.10	1.11	0.99	1.04	1.10
	Singapore	1.93	2.07	1.92	1.92	2.08	2.17	2.07	1.90	1.81	1.89	..
	South Africa	0.74	0.73	0.73	0.72	0.77	0.80	0.82	0.83	0.75	0.68	..
	Chinese Taipei	2.82	2.91	2.96	3.00	2.98	3.00	3.09	3.19	3.35	3.49	3.63

Source: OECD Stat. [Data extracted on 20 Mar 2023 17:46 UTC \(GMT\) from OECD.Stat.](#)

e: Estimated value, b: Time series break, p: Provisional value, d: Definition differs, v: The sum of the breakdown does not add to the total, m: Underestimated or based on underestimated data.

Appendix 20: How Access to Micro Data Sets in Turkish Statistical Institute?

Turkish Statistical Institute (TURKSTAT) provides many micro data sets (data collected on individual firms) that separated into two groups of data as Group-A and Group-B. Researcher can access to the Group-A Data only within Data Research Centers (DRCs) in many cities⁸⁷ in Türkiye. However, Group-B Data is available for dissemination of information.

To use those micro data sets, the researcher must follow many phases such as reading, application, and approval. In reading phase, the researcher must read carefully “Turkish Statistical Institute, Instructions for the Access and Use of Micro Data” document on TURKSTAT website. In the application phase, to access *Micro Data Request Form*, the researcher must have an e-Government Gateway account, then fill the form and send it. In the approval phase, the researcher’s institution must sign (by Rectorate) a physical copy of the form (protocol). It is important to work at DRCs without expenses. Moreover, the protocol must be renewed every year to continue the research. Otherwise, the researcher must pay to study at DRCs even if researcher is a student and data is provided by public institution, TURKSTAT.

⁸⁷ Ankara (Head), İstanbul, İzmir, Adana, Antalya, Gaziantep, Van, Erzurum, Zonguldak, Edirne, Konya, Diyarbakir, and Samsun.

CURRICULUM VITAE

Atakan AKINCI completed his bachelor's degree at Istanbul University, the Faculty of Political Sciences, Department of Public Administration in 2012. He also held two more bachelor's degrees at Anadolu University such as Economics (Faculty of Economics) in 2013, and Management Information Systems (Faculty of Open Education) in 2021. He started his master's degree in Economics (in English) at Yildiz Technical University, Graduate School of Social Sciences, Department of Economics in 2013, and completed his master thesis in 2016 with the thesis titled "Information and Communication Technologies and Economic Institutions". He received Erasmus+ grant to study in Parma/Italy and completed 5 months of his master's degree in International Business and Development at University of Parma, Faculty of Economics in 2015. He started his doctorate degree in Economics (in English) at Istanbul University, Institute of Social Sciences in 2017 and finished it in 2023. He has worked as a lecturer since 2020 at Piri Reis University.

Projects

- Moderator (4 Months / 1.12.2018 – 31.03.2019)
Ipsos, Research Project
Research on Understanding of Türkiye's Investment Climate
- Researcher (2 Years / 26.01.2015 - 26.01.2017)
Yildiz Technical University, Scientific Research Projects Coordinator, Master Research Project (YÜLAP)
Project Name: Information and Communication Technologies and Economic Institutions
Project No: 2015-02-01-YL01
Project Manager: Prof. Dr. Feride Gönel

Articles Published in International Scientific and Peer-Reviewed Journals

- Feride Gonel, Atakan Akinci. (2018) “How does ICT-use improve the environment? The case of Turkey”, World Journal of Science, Technology and Sustainable Development, Vol. 15 Issue: 1, pp. 2-12, <https://doi.org/10.1108/WJSTSD-03-2017-0007><https://doi.org/10.1108/WJSTSD-03-2017-0007>

Articles Published in National Scientific and Peer-Reviewed Journals

- Atakan Akinci, Hasan Vergil. (2023) “Effect Of R&D On Product and Process Innovation in The Turkish Manufacturing Industry”, Beykent University Journal of Social Sciences, Vol. 16 Issue: 1, pp. 8-25, <https://doi.org/10.18221/bujss.1189913>

Papers Presented at International Scientific Meetings and Published in Proceedings Books

- Akinci, A. (2023). Comparison of Türkiye and European Union Countries in terms of R&D Expenditures and R&D Personnel. 17th UBAK International Scientific Research Congress, Social and Educational Sciences, 19 - 20 August 2023, Ankara.
- Gönel, F., & Akinci, A. (2016). How Does ICT-Use Improve the Environment? The Case of Turkey. 2nd International Annual Meeting of Sosyoekonomi Society Proceedings Book. 2nd International Annual Meeting of Sosyoekonomi Society. Sosyoekonomi Society. Amsterdam, The Netherlands, <http://www.sosyoekonomijournal.org/AMSS16PB.pdf>
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