

ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL

**R&D EXPENDITURES AND ECONOMIC GROWTH: A PANEL DATA
ANALYSIS FOR SELECTED DEVELOPING ECONOMIES**



M.Sc. THESIS

Furkan KALIN

Department of Economics

Economics M.Sc Programme

JUNE 2023

ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL

**R&D EXPENDITURES AND ECONOMIC GROWTH: A PANEL DATA
ANALYSIS FOR SELECTED DEVELOPING ECONOMIES**



M.Sc. THESIS

**Furkan KALIN
(412201024)**

Department of Economics

Economics M.Sc Programme

Thesis Advisor: Asst. Prof. Dr. Mete Han YAĞMUR

JUNE 2023



**AR-GE HARCAMALARI VE EKONOMİK BÜYÜME: SEÇİLMİŞ
GELİŞMEKTE OLAN EKONOMİLER İÇİN PANEL VERİ ANALİZİ**

YÜKSEK LİSANS TEZİ

**Furkan KALIN
(412201024)**

İktisat Anabilim Dalı

İktisat Yüksek Lisans Programı

Tez Danışmanı: Dr.Öğr.Üyesi Mete Han YAĞMUR

HAZİRAN 2023



Furkan Kalın, a M.A student of ITU Graduate School student ID 412201024, successfully defended the thesis entitled “R&D EXPENDITURES AND ECONOMIC GROWTH: A PANEL DATA ANALYSIS FOR SELECTED DEVELOPING ECONOMIES”, which he prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

Thesis Advisor : **Assist. Prof. Dr. Mete Han Yağmur**
Istanbul Technical University

Jury Members : **Assist. Prof. Dr. Shourjo Chakravorty**
Istanbul Technical University

Assist. Prof. Dr. Mahmut Sami Güngör
Marmara University

Date of Submission : 26 May 2023

Date of Defense : 21 June 2023



FOREWORD

I am particularly interested in R&D in the developing world as a data scientist. As a result, I concentrated on this thesis's analysis of the benefits of R&D, particularly for developing nations.

I would like to thank Asst. Prof. Dr. Mete Han YAĞMUR , who served as my thesis advisor during the writing process.

My family, Niyet EVDONDEREN, the dearest to me in my life, and my close friend Furkan ALVER deserve my gratitude for their moral and material support throughout the research process.

June 2023

Furkan KALIN



TABLE OF CONTENTS

	<u>Page</u>
FOREWORD	vii
TABLE OF CONTENTS	ix
ABBREVIATIONS	xi
LIST OF TABLES	xiii
LIST OF FIGURES	xv
SUMMARY	xvii
ÖZET	xix
1. INTRODUCTION	1
1.1 Current Developments in Global Technologies	4
2. LITERATUR REVIEW	11
2.1 Economic Growth	11
2.2 R&D Based Endogenous Growth Models	13
2.2.1 Romer Model (1990).....	13
2.2.2 Jones model as a semi-endogenous growth model	15
2.2.3 Grossman and Helpman’s model	17
2.2.4 Aghion and Howitt model	20
2.2.5 Acemoğlu and Zilibotti model	26
2.2.6 Schumpeter model.....	28
2.3 R&D	29
2.3.1 Theory on the impact of R&D	31
2.3.2 Empirical evidence on the impact of R&D	32
3. DATA AND METHODOLOGY	37
3.1 Dataset.....	37
3.2 Serial Correlation And Heteroskedasticity.....	39
3.3 Cross Sectional Dependence	40
3.4 Simple Linear Regression	41
3.5 Econometric Model.....	43
3.6 The Random Versus Fixed Effects Model	46
3.7 Results For Fixed Effect Regression Model	46
3.8 Hausman Test For Endogeneity of The Model	47
3.9 Results	48
4. CONCLUSION	51
REFERENCES	53
CURRICULUM VITAE	63



ABBREVIATIONS

BRL	: Brazilian Real
BRICS	: Brazil, Russia, India, China and South Africa
CES	: Consumer Technology Association
CLP	: Chilean Peso
COP	: Colombian Peso
CSW	: Commission on the Status of Women's
EM	: Emerging Markets
EU	: European Union
FE	: Fixed Effect
FED	: Federal Reserve Bank
G7	: The Group of Seven
GDP	: Gross Domestic Product
HAC	: Heteroskedasticity and Autocorrelation-Consistent
HDI	: Human Development Index
IDR	: Indonesian Rupiah
INR	: Indian Rupee
KRW	: South Korean Won
LMIC	: Low And Middle-income Country
OECD	: Organisation for Economic Co-operation and Development
OLS	: Ordinary Least Squares
PEN	: Peruvian Sol
R&D	: Research and Development
RE	: Random Effect
RUB	: Russian Ruble
SGD	: Singapore Dollar
THB	: Thai Baht
TRY	: Turkish Lira
UAE	: The United Arabic of Emirates
SCC	: The Cross-sectional and Serial Correlation



LIST OF TABLES

	<u>Page</u>
Table 1.1 The change of selected nations' national currencies against the dollar between 2000 and 2023.....	9
Table 2.1 R&D expenditure as a percentage of GDP	30
Table 3.1 Country List	37
Table 3.2 A description of the series used in the analyses	38
Table 3.3 Results of Breusch-Godfrey/Wooldridge test for serial correlation in panel models	39
Table 3.4 Results of Breusch-Pagan test.....	40
Table 3.5 Pesaran CD test for cross-sectional dependence in panels	40
Table 3.6 Descriptive statistics and names of variable	41
Table 3.7 Average of variabeles by country between 2000-2020.....	41
Table 3.8 Correlation Matrix.....	42
Table 3.9 Result of OLS.....	42
Table 3.10 The Relationship between R&D Expenditures and Economic Growth...	47
Table 3.11 Multiple regression using fixed effect model.	47
Table 3.12 Results of Hausman Test.....	48
Table 3.13 Results of HAC	48
Table 3.14 Comparison of Coefficients and Signifiance	49



LIST OF FIGURES

	<u>Page</u>
Figure 1.1 Exports of High Technological Products (ratio to manufacturing industry exports, %)	3





R&D EXPENDITURES AND ECONOMIC GROWTH: A PANEL DATA ANALYSIS FOR SELECTED DEVELOPING ECONOMIES

SUMMARY

Growth theory suggests that technological development is the primary determinant of long-term economic growth, and research and development (R&D) activities are considered the driving force of technological development. This study aims to investigate the relationship between economic growth and R&D spending. To this end, we study the relationship between gross domestic product (GDP) per capita and the ratio of R&D expenditures to GDP in a group of developing and newly developed economies (namely, Brazil, Chile, Colombia, Indonesia, India, Peru, Republic of Korea, Russian Federation, Singapore, Thailand, and Türkiye) using annual data from 2000 to 2020. Using the fixed effects model, a panel data analysis is estimated, where gross domestic product (GDP) per capita is used as the dependent variable and R&D expenditures as a ratio of GDP is used as an independent variable. We also utilized gross fixed capital formation, labor force, and aggregate government expenditures as a ratio of GDP as control variables. The results indicate a significant and positive relation between R&D spending and economic growth. Specifically, a 1% increase in R&D expenditures leads to a 0.27% increase in GDP per capita. We also find that the model's control variables have positive and significant effects on economic growth. Given its favorable impact on economic growth, especially developing countries may be advised to allocate more resources to R&D activities.



AR-GE HARCAMALARI VE EKONOMİK BÜYÜME: SEÇİLMİŞ GELİŞMEKTE OLAN EKONOMİLER İÇİN PANEL VERİ ANALİZİ

ÖZET

1980'lerin ikinci yarısından sonra ortaya çıkan ve ülkeler arasındaki ekonomik büyüme farklılıklarını inceleyen içsel büyüme teorileri, daha önceki modellerin aksine teknolojiyi içselleştirmiş ve ekonomik büyümenin itici güçlerinden biri olarak tanımlamıştır. İçsel büyüme modelleri, ekonominin teknolojik ilerlemeye ne kadar çok kaynak ayırırsa, o kadar hızlı büyüyeceğini ve gelişeceğini öngörmektedir.

Teknolojideki ilerleme, fiziksel ve beşeri sermaye, doğal kaynaklar ve nüfusa dayalı işgücündeki artış, büyümeye katkıda bulunan faktörlerden bazılarıdır. Bugüne kadar geliştirilen çalışma ve modellere göre bilgi kullanılarak üretilen Ar-Ge faaliyetleri, ulusların refah düzeyini ve kalkınmasını etkileyen en önemli üretim kaynakları arasında yer almaktadır.

Ulusların sahip olduğu fiziksel ve beşeri sermaye miktarı, yeni ürünler ve üretim yöntemleri için gerekli olan yeni teknolojilerin üretimini belirlemektedir. Ülkelere göre Ar-Ge girişimleri patent sayısı, Ar-Ge çalışanlarının sayısı ve ekonomide Ar-Ge harcamalarına ayrılan yatırımların gayri safi yurtiçi hasılaya oranı, ülkenin Ar-Ge faaliyetlerini ölçmek için kullanılabilir.

İktisat literatüründe üretim kaynaklarını ele alan çok sayıda büyüme teorisi bulunmaktadır.

Brezilya, Şili, Kolombiya, Endonezya, Hindistan, Peru, Rusya Federasyonu, Singapur, Tayland, Güney Kore ve Türkiye, 2000-2020 yıllarına ait yıllık verilerinin mevcut olduğu bu çalışmanın kapsadığı ekonomik açıdan kırılgan 11 ülke arasında yer almaktadır. Çalışmada ekonomik büyüme bağımlı değişken, Ar-Ge harcamaları açıklayıcı değişken, brüt sabit sermaye oluşumu, hükümet hacamaları ve işgücü kontrol değişkenleri olarak belirlenmiş ve irdelenmiştir.

İlk olarak, çalışmanın ampirik analizi için değişkenler teker teker modele eklenmiştir. Önce doğrusal regresyon ile modeller incelenmiştir. Ardından Sabit etkiler tahmin ediciler ve rastgele etkiler tahmin ediciler kullanılarak farklı modeller oluşturulmuştur. Panel veri analizini tamamlamak ve sabit etki ve rastgele etki modellerinden

hangisinin daha uygun olduğunu belirlemek için Hausman testi kullanıldı. Analiz, tüm değişkenleri dahil ederek üretilen değiştirilmiş modelin uygun model olduğu ve bu sonucu ifade eden sabit etkiler modelinin geçerli model olduğu sonucuna varılmıştır. Birim kök test, otokorelasyon ve eş varyanslık testlerine göre değişkenlerin anlamlılığı kontrol edilmiştir.

Modelde Ar-Ge harcamaları değişkeninin katsayısının hem pozitif hem de istatistiksel olarak anlamlı olduğu görülmüştür. Bu ana modelde panel veri testleri çalıştırılmış ve sonuca varılmıştır. Bu model, Ar-Ge harcamalarının GSYİH'ye oranında % 1'lik bir artışın, seçilmiş ülke grubunda kişi başı GSYH'de % 0,27'lik bir artışa yol açacağını öngörmektedir.

Analiz bulguları, modelin işgücü kontrol değişkenlerinin ve yurt içi yatırım kontrollerinin ekonomik büyüme üzerinde olumlu bir etkiye sahip olduğunu göstermektedir. Modele göre, brüt sabit sermaye yatırımlarının GSYİH içindeki payındaki %1'lik bir artış, bu ülkelerde ekonomik büyümede %1,47'lik bir artışa neden olmakta; istihdamdaki %1'lik bir artış, ekonomik büyümede %3,11'lik bir artışa neden olmakta; devlet harcamalarının GSYİH içindeki payının %1 artması bu ülkelerde ekonomik büyümenin %1,07 artmasına neden olmaktadır.

Çalışma bulguları, 11 ülkenin ekonomik verileri analiz edildiğinde, Ar-Ge harcamalarının, iş gücünün, hükümet harcamalarının ve brüt sermaye yatırımlarının istatistiki olarak anlamlı ve pozitif etkisi vardır.

Katsayı büyüklüklerine göre ekonomik büyüme üzerinde en fazla pozitif etkinin işgücü olduğu, bunu da sırasıyla, brüt sermaye yatırımları, devlet harcamaları ve Ar-Ge harcamaları takip etmektedir. Dolayısıyla, sonuçlarımız, literatür taraması bölümünde yer alan ve Ar-Ge harcamalarının ekonomik büyüme üzerinde pozitif ve anlamlı bir etkiye sahip olduğunu gösteren çalışmaların çoğuyla uyumludur.

Özellikle cari açık veren ülkeler ihracatlarının değerini artırmalı ve katma değeri yüksek ürünlerin ithalatına daha az bel bağlamalıdır. Yüksek Ar-Ge harcamaları genellikle ülkelerin yüksek teknolojiye yani katma değeri yüksek ürünler üretmesini sağladığından, gelişmekte olan ve kırılgan ekonomilerin Ar-Ge faaliyetlerini artırması özellikle önemlidir.

Ar-Ge harcamalarının kırılgan ülkelerin büyüme istikrarı üzerindeki etkisini analiz etmek için daha fazla araştırma yapılabilir. Spesifik olarak, Ar-Ge faaliyetleri ülkelerin

daha yüksek katma değerli ürünler üretebilmelerini sağladıkça, yabancı sermayeye olan bağımlılıklarının azalacağı ve bunun karşılığında daha istikrarlı ve daha yüksek büyüme oranlarına sahip olabilecekleri çıkarımı yapılabilir. Ar-Ge sektörü başta olmak üzere doğrudan yabancı yatırımların etkileri göz önünde bulundurulduğunda, hukuk sisteminin, yolsuzlukla mücadele kurallarının ve fikri mülkiyet haklarının korunmasının ekonomilerin büyümesine ve ekonomik istikrara etkisinin analiz edilmesi de önemlidir.





1. INTRODUCTION

Emerging market economies have become more significant to the global economy over the past few decades. Their quickening integration into international trade and financial networks goes hand in hand with their growing significance. Emerging markets' share in global output and global output growth increased from one-tenth and one-fifth, to more than a quarter and more than a half, respectively (IMF, 2022).

About 80% of the output of all emerging markets comes from the seven biggest emerging economies—China, Russia, India, Brazil, Türkiye, Mexico, and Indonesia. Similar to the G7 (the Group of Seven major advanced economies), this group, which is commonly referred as EM7, has also been the primary driver of growth in emerging markets and their integration into the global economy. Particularly with those in their respective neighborhoods, the EM7 economies have strong trade and financial ties with other emerging markets (EM) and frontier markets (FM). Egypt, Indonesia, Mexico, South Korea, Saudi Arabia, Taiwan, and Türkiye round out the top ten emerging and developing economies by nominal or PPP-adjusted GDP, along with the other four BRICS nations (Brazil, Russia, India, China, and South Africa) growth in the EM7 could have significant global economic spillovers due to their size and integration.

A sovereign nation that has a less developed industrial base and a lower Human Development Index (HDI) than other nations is considered to be a developing country. However, there are several related terms and there is no consensus on which one describes the status of nations the best. Low and middle-income country (LMIC) is a term that is frequently used interchangeably with the term developing countries. Based on gross national income per capita, the World Bank divides the world's economies into four categories: high, upper-middle, lower-middle, and low income countries. Subgroups of developing countries include small island developing states, landlocked developing states, and least developed countries. The term "high-income countries" or "developed countries" is typically used to describe nations at the other end of the spectrum.

A market that shares some traits with a developed market but falls short of that market's standards is referred to as an emerging market (or an emerging country or an emerging economy (O'Sullivan, Sheffrin, 2003). This includes markets that are now or have

previously been developed markets (United Nation, 2010). Developing nations with less developed, riskier, or illiquid capital markets are referred to as "frontier markets" (World Bank, 2015).

Emerging markets are characterized economically by low income, high growth economies that rely heavily on market liberalization. Undoubtedly, emerging economies can progress past this stage and move into the post-emerging stage. Emerging markets become emerged markets once they "graduate" from that economic status. Israel, Poland, South Korea, Taiwan, the Czech Republic, and city-states like Singapore have made the transition from emerging to "emerged" nations. Compared to those classified as emerging markets, these markets tend to have higher incomes and more stable political systems.

A research analyst at Morgan Stanley coined the phrase "Fragile Five" in August 2013 to describe five emerging market economies whose growth prospects are excessively dependent on shaky foreign investment. The fragile group's initial five members are Indonesia, South Africa, Brazil, India, and Türkiye. The nations that comprise the same group level suffer from issues including high inflation, a current account deficit, and slow economic expansion. These nations continued to encounter issues in 2015 as capital shifted from developing markets to industrialized nations. Via contagion pathways, these issues spread to other developing markets, and in reaction to capital flight from these emerging market nations. Accordingly, Morgan Stanley analysts expanded the "Fragile Five" to the "Troubled Ten" in the middle of 2015. Taiwan, Singapore, Russia, Thailand, South Korea, Peru, South Africa, Chile, Colombia, and Brazil were listed as the "Troubled Ten" economies. The fragile five and troubled ten economies are the nations with economic problems as a result of their significant foreign trade deficit. These raise the issue of dependence on US monetary policy. The US Federal Reserve began three rounds of quantitative easing at the end of 2008, and these periods have significantly impacted capital flows from most emerging market nations.

These countries might experience vulnerability due to different macroeconomic characteristics as well. For example, when the data on central government borrowing in Singapore between 2010 and 2020 are analyzed, its ratio to GDP is over 100%. Türkiye, on the other hand, is the country with the highest foreign trade deficit among the countries on the list; between 2010 and 2020, trade deficit of Türkiye has been

around more than 3% of GDP. In general, foreign trade deficit can be seen as a sufficient reason for countries to get into trouble. Also, China's slowdown shows that it is vulnerable to currencies among these countries. In the current situation, even if countries such as Korea and Singapore do not have a high foreign trade deficit, these countries may also be geographically vulnerable due to their bilateral relations with China. (Redeker, 2015)

A common problem that most EM encounter is high trade and current account deficits, and in return, their dependence on international liquidity and foreign capital inflows. In order to mitigate their macroeconomic vulnerability in this respect, EM may decrease their foreign dependency by means of decreasing their trade deficit. While many EM are part of the global value chain, some of them largely produce and export low value-added products. For instance, while Türkiye's ratio of medium and high technology products' exports to total industrial exports has been around 30%, its high technology product's ratio to total industrial export is only about 3%.

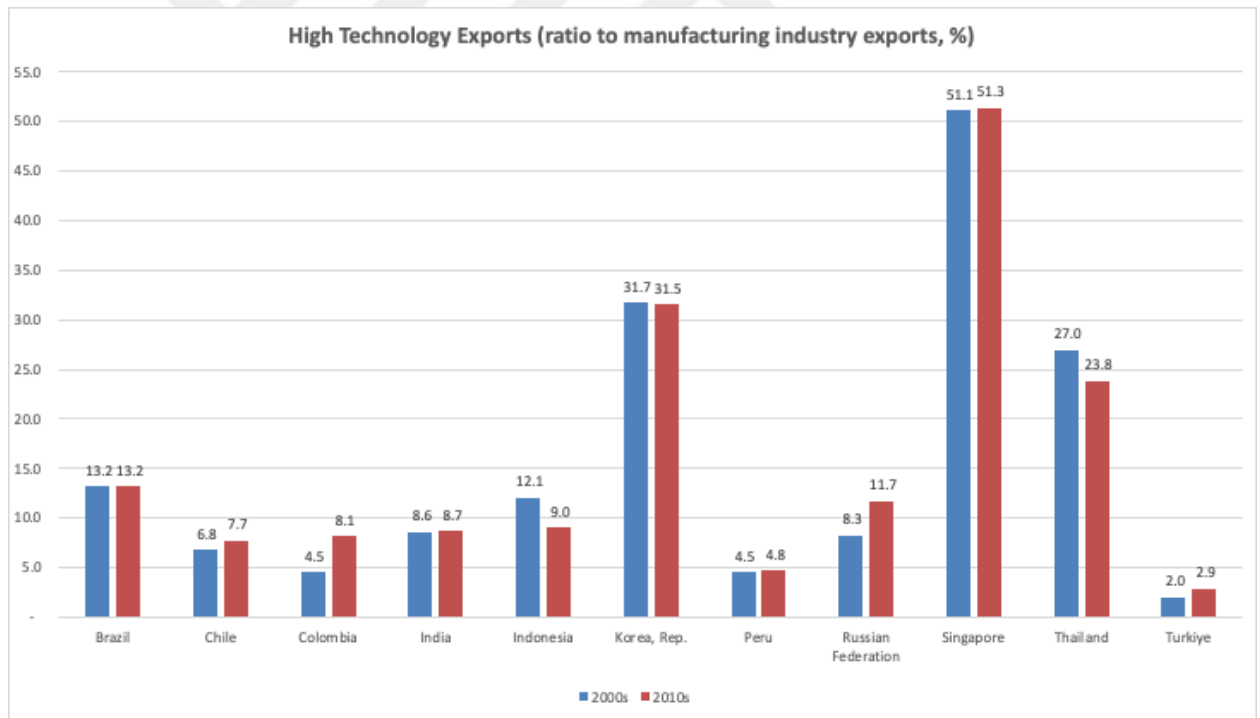


Figure 1.1 Exports of High Technological Products (ratio to manufacturing industry exports, %)

Figure 1.1 shows that when the ratio of high-technological products in exports of Singapore, Korea and Thailand is analyzed, it is seen that they are positively differentiated compared to other countries. While it is seen that Türkiye has the lowest

percentage among the selected countries, it is seen that Colombia, Chile and Türkiye have increased this rate in 10-year changes compared to the previous 10-year period. Even though the percentage has decreased in Thailand, it is still around 25%.

In general, it is seen that the high technology export tendency is different in selected countries. Although these countries have different export spectrums, they have different vulnerabilities, and each country has a different characteristic. If we look at the relationship of this situation to the local currency, we will show this in the following sections. Singapore, Korea and Thailand seem to be at the forefront of local currency stability and there is a correlation between these two data. However, these countries may have a different vulnerability compared to other countries due to their close trade with China, and this should not be ignored.

Among industrial goods, high value-added products are typically the high-technology products. Countries that need to import such high-value-added products or that cannot produce and export high-value-added products commonly give trade deficits. In order to mitigate their trade deficit, and thereby their reliance to foreign capital, EM should be increasing the share of high-technology productions and exports. High value-added nature of high technology products also contributes to growth of countries. Since economic growth is particularly important for the welfare of households in EM, producing high-technology products is critical for EM. Since an important determinant of producing high-technology products is R&D activities, we assert that policy makers should be allocating enough resources for product development and innovation. Against this background, this thesis investigates the eleven countries Singapore, Russia, Thailand, South Korea, Peru, Chile, Brazil, Türkiye, Indonesia, and India in terms of their economic infrastructure, economic features, and the impact of R&D spending on economic growth via empirical analysis.

1.1 Current Developments in Global Technologies

In this section, current technological developments in the world, developments in the fields of sustainability and digital economy will be discussed. These developments are factors that directly or indirectly affect R&D developments and affect the growth of countries and companies.

The UN has selected seventeen universally supported sustainable development objectives and is mobilizing broad support for commitments in all sectors to make the

world a safer and better environment for all people. These objectives, which 193 United Nations member states overwhelmingly endorsed in 2015, are currently influencing global regulatory environments. The 17 sustainable development goals (SDGs) are included in the comprehensive, integrated strategy of human security.

The 17 integrated goals are formulated as no poverty, zero hunger, good health and well-being, quality education, gender equality, clean water and sanitation, affordable and clean energy, decent work and economic growth, industry, innovation and infrastructure, reduced inequalities, sustainable cities and communities, responsible consumption and production, climate action, life below water, life on land, peace, justice and strong institutions, partnerships for the goals.

On the other hand, this year, “human security for all” was the central theme of the Consumer Technology Association (CES) 2023, which was held in Las Vegas, USA on 5-8 January 2023. One of the CES's important topics was the importance of developing and applying innovative technologies to meet real human needs. These human needs have been created based on sustainable development goals. CES 2023 explores sustainable ways to advance human security through technological innovation since the assembly believes in this kind of technology has a critical role in human security. CES creates seven security pillars that are related to a person's experience in life and make up human security, which recognizes the significance of personal welfare; food security, access to healthcare, economic security, environmental protection, personal safety & mobility, community security, and political freedom. CES asserts it can be influenced the future of humans by contributing to the discovery of fresh approaches to some of humanity's most critical problems.

The importance of technology and innovation has grown, and as more women participate in it, technology is developing more quickly around the globe. IWD 2023 held on March 8, 2023, with the theme "DigitALL: Innovation and technology for gender equality." The key theme for the Commission on the Status of Women's 67th Session (CSW-67), "Innovation and technological transformation, and education in the digital age for achieving gender equality and the empowerment of all women and girls," is in line with this theme.

Undoubtedly, the need for technology does not arise spontaneously. Humankind has had extraordinary situations that triggered us to think more about technology. The

outbreak of the COVID-19 pandemic has changed international trade relations. During the COVID-19 pandemic, consumers, brands, and merchants continued to find themselves on unfamiliar ground. Even after lockdowns were released, consumers continued to feel unsure, nervous, and terrified. They tended to try to figure out how to adapt to their nearly weekly changes in expectations, routines, and mental health. Day-to-day life has changed, consumers spent more time at home and the willingness of high-cost products declined. Global GDP decreased by 3.3% in 2020 compared to 2019. Even if, it has increased by 6.1% in 2021 compared to 2020, it has again decreased and reached below the average of the last ten year's growth rate by 3% in 2022.

Changing consumer purchase behaviour led companies and big sectors to review other markets and the management of crises. One of the most efficient ways has been to reach the audience via e-commerce, q-commerce and m-commerce. Especially the routine traditional selling ways like brick-and-mortar retail struggled to keep up during the international lockdown and had to transform physical store sales and marketing strategies and transferred some of its market shares to online commerce.

Countries and companies have become more competitive at online commerce. The largest online retailers in the USA, Canada, and the European nations under study account for almost 50% of online buying instances. Almost 40% of internet shopping activities are accounted for by Amazon, which blatantly dominates. In order to replace or upgrade consumer electronics, including smartphones, digital devices, Smart TVs, and home appliances, 48% of customers worldwide go online. In the UAE, Saudi Arabia (KSA), and India, it is below the worldwide average, whereas in the USA, Canada, the UK, France, Korea, and Japan, it is 60% or higher.

Having a gradual increase in e-commerce sales has led to a sharp rise in the development of online technologies like Artificial Intelligence, Augmented Virtuality, Virtual Reality, Meta Platforms and FinTech.

The new demands of consumers changed trading, marketing and sales strategies in both online and offline markets. Not only pandemic had led to different marketing and selling strategies in the business but also different perspectives and consuming attitudes of the new generation (GenZ) forced nationals and companies to find new ways in order to sustain economic growth.

The importance of R&D has risen with the increase in technological investments made with classical methods such as electronics and mechatronics, as well as more digital and artificial intelligence-supported technological investments. R&D is the creative and methodical work done to increase the body of knowledge, including our understanding of people, culture, and society, as well as to find new applications for the knowledge that already exists. The total of deliberate actions taken by R&D performers in an effort to produce new knowledge is referred to as an "R&D activity." Most of the time, "R&D projects" can be formed by grouping together R&D activities. Even at the lowest level of formal activity, each R&D project consists of a set of R&D activities, is organized and managed for a particular purpose, and has its own goals and anticipated outcomes.

The topic of high-tech production is extremely pertinent and timely today when every nation is looking for workable solutions to restart sustainable economic growth. When compared to medium-high tech or low-tech sectors in times of crisis, the high-tech industry has demonstrated its inherent strength among EU countries.

The Standard International Trade Classification divides high-tech goods into nine categories: armament, aerospace, computers and office equipment, electronics-telecommunications, pharmacy, scientific instruments, electrical machinery, and non-electrical machinery.

From the perspective of real EU convergence, a positive relationship between R&D and high-tech export mentioned in some papers is significant. Reduced disparities in R&D expenditures among EU nations may encourage the export of high-tech goods and accelerate economic growth.

Given the significance of the technological intensity of exports as a tool for achieving economic growth, a substantial body of empirical literature has been generated that examines the drivers of the technological intensity of exports. The research by Seyoum (2004), which uses data from 54 geographically dispersed countries to analyze the role of variables like human capital, technology, domestic demand, competition, exchange rate, and foreign investment on the technological level of countries' exports, is among the earliest studies in the analysis of the drivers of technology-intensive exports.

Braunerhjelm and Thulin's 2008 analysis of the high-tech exports of 19 OECD nations between 1981 and 1999, found evidence of the beneficial contribution of R&D

spending to exports of manufactured goods with higher technology content as well as to the determination of comparative advantage between nations.

The quality of human capital, foreign direct investment, and countries' openness to international trade are key factors in the export performance of countries that export high-tech products, according to Tebaldi (2011), who examined high-tech exports drivers between 1980 and 2008 based on data from a wide range of economically and geographically highly heterogeneous countries.

Basarac et al. (2013) investigated the factors that influence the exports of high-tech manufactured goods from EU nations and came to the conclusion that local demand and industrial production are significant factors.

The results of Sandu and Ciocanel's (2014) study on the effect of innovation and R&D spending on high-tech exports for EU nations confirmed a positive association between overall R&D spending and the volume of high-tech exports.

In the last years, Panda and Sharma (2020) used the revealed technological advantage (RTA) index and the revealed symmetric technological advantage (RSTA) index to examine the technological specialization of nations in various fields and its impact on high-technology exports in developing nations. They discover compelling evidence that specialized technological development leads to high-technology export. In their investigation of the effects of scientific productivity on high-technology exports in a few developing nations between 1996 and 2017, Sepehrdoust et al. (2021) came to the conclusion that risks like economic risk, scientific risk, financial risk, and political risk have a significant impact on high-technology export.

Over the past ten years, there has been an increase in the global trade of high-tech goods. Numerous studies demonstrate that high-tech product imports and exports both enhance competitiveness. The European Commission's policy objectives of environment and climate, our digital future, and jobs and economy all place a high priority on the use of high-tech products.

According to one of the studies regarding the trade of high-tech goods outside the EU, between 2011 and 2021, the total extra-EU trade in high-tech goods increased by an average of 4.9% per year. High-tech products now account for 18.1% of all trade, up from 14.7% in 2011 and 14.7% in 2010. The primary trading partner for high-tech goods entering the EU was China. The main trading partner for high-tech exports from

the EU was the United States. Between 2011 and 2021, sold production of high-tech goods increased from €258 billion to €368 billion.

China (38%) and the United States (19%) accounted for more than half of the EU's imports of high-tech goods from non-EU nations in 2021. Imports increased from €248 billion to €392 billion between 2011 and 2021, representing an average annual growth rate of 4.7%. The top six partners' imports from China rose the most in value, from €82 billion to €148 billion, while Vietnam's average annual growth rate was the highest at 18.6%.

When we look at the local currencies of the countries in the study, we should see different features. We can see that the Turkish lira has been declining more recently. In contrast to other currencies, the Brazilian real and Colombian peso's decline after 2020 stands out. Strong currencies include the South Korean Won, Thai Baht, and Singapore Dollar. While the Korean won, Peruvian sol, Singapore dollar, and Thai baht have been relatively stable, It should also be taken into account that these countries export high-tech products more than others, while other countries' currencies have been quite volatile and they have depreciated significantly. For instance, the Turkish lira depreciated more than 150% between January 2021 and January 2023.

Table 1.1 The change of selected nations' national currencies against the dollar between 2000 and 2023.

	TR Y	BR L	RU B	CL P	CO P	IDR	IN R	KR W	PE N	SG D	TH B
01.01.2023	18.7	5.2	69.9	848	4848	15490	82.6	1261	3.8	1.34	34.1
01.01.2022	13.2	5.5	74.6	852	4070	14255	74.4	1189	3.9	1.35	34.2
01.01.2021	7.44	5.1	74.4	710	3422	13910	73.1	1085	3.6	1.32	31.1
2010-2020	2.9	2.8	48.7	594	2515	11904	60.3	1124	3	1.34	32.09
2000-2010	1.34	2.3	28.8	573	2307	93123	45.3	1122	3.2	1.61	37.3

The aforementioned nations use comparable remedies for comparable issues. Brazil, for instance, has managed its own high inflation by keeping sources like oil under control. In order to have a boom in investments and to provide a secure environment for the economy, arrangements must be made. Similar measures were used by India to

limit the import of gold to help the economy. The minor improvement in India is undone by the FED's choices. Türkiye, which has less public debt than Brazil and Indonesia, unavoidably requires portfolio investment. The economy of South Africa, which is plagued by internal issues, suffered as a result of capital losses brought on by the FED's tightening of monetary policy. In a similar vein, the FED's actions lowered the value of the Indonesian rupee.

In 2021, South-Eastern Asia had the highest total merchandise trade to GDP percentage at 167.8 percent. Europe has the biggest share of exports accounting for 35.8 percent of total exports followed by Eastern Asia at 26.6 percent.



2. LITERATUR REVIEW

2.1 Economic Growth

One of the most fascinating and most exciting subfields of economics is still economic growth. This interest is undoubtedly related to issues that economic growth addresses.

In its simplest form, the idea of economic growth can be defined as the gradual increase in a nation's economic output. The variations in the countries' GDP are one of the growth indicators in this production (Jackson & McIver, 2001). Both developed and developing nations have serious concerns about the phenomenon of economic growth.

However, while developed countries typically place more emphasis on increases in GDP, developing countries typically attach more importance to economic development, including the concept of economic growth, ensuring income justice in the nation, increasing employment, and decreasing inflation. Inquiry is present.

Numerous theories about economic growth have been developed in the literature. Classical growth models, Keynes' growth models, and contemporary growth models are the most well-known of these theories. Since growth theories are not the focus of this study, they will only be briefly mentioned.

Among the founders of the traditional growth theories are Adam Smith and Thomas Malthus. This theory holds that investments should follow savings as the foundation for economic growth. Growth will take place in this situation as the investments and savings made raise the productivity of the soil and labor. A decline in savings will result in a decline in investments, which will slow the rate of economic expansion.

Smith generally based his ideas on the division of labor. According to Smith, the expansion of the division of labor will increase output per worker by boosting labor productivity, and as a result, the rise in output will be beneficial for the expansion of the economy. According to Malthus, there is an inverse relationship between population growth and economic expansion. In other words, he argued that if population growth outpaces the production of agricultural goods, economic growth will suffer because people will have less money to save as a result of falling per capita income.

In his book "The General Theory of Employment, Interest, and Money" published in 1936, Keynes advanced the idea that in the event of a severe and protracted economic collapse, governments should engage in deficit spending in order to hire the long-term unemployed. Keynes created all of these ideas that are now fundamental to contemporary macroeconomics in this socioeconomic context. The multiplier effect, which is calculated as a response to the marginal propensity to consume, is a key component of Keynesian theory and states that government investments made during recessions are beneficial.

A few years after Keynes, Samuelson updated the multiplier effect by fusing it with the concept of acceleration (Capital/Output). As a result, investments in the expansion phase of the business cycle are now influenced not only by multiplier effects but also by the need for businesses to invest in new factories and products. The idea that the Keynesian multiplier effect on government investments may also result in private sector investment through the acceleration effect is crucial in this situation. The Samuelson multiplier-accelerator effect is another name for this accelerator and multiplier effect combination in macroeconomics.

On the other hand, there are two types of contemporary growth theories: exogenous growth and internal growth. The Harrod-Domar model and the Neo-Classical Growth model are well-known exogenous growth theories. The core issue, according to the Harrod-Domar model, is whether the economy will eventually achieve full employment. One good is produced in this model. The public does not engage in any economic activity, so there are no public expenditures. Additionally, the model has not advanced technically, and the economy is closed. According to the neo-classical growth theory, labor and capital determine the level and volume of output.

If we look at endogenous growth models, the works of Romer (1986) and Lucas (1988) stand out first. In these theories, growth is provided by human capital, technical and technological knowledge and R&D expenditures. Compared to exogenous growth models, the main feature of endogenous growth models is that they attach importance to increasing productivity in production and the necessity of R&D expenditures.

Romer (1986) and Lucas (1988) are two authors whose work on endogenous growth models stands out as the best. According to these theories, human capital, technical and technological knowledge, and R&D expenditures all contribute to growth. The main distinction between endogenous growth models and exogenous growth models

is the weight they place on increasing production productivity and the necessity of R&D expenditures.

2.2 R&D Based Endogenous Growth Models

Globalization has had a significant impact on R&D, as it has in many other fields. The importance of R&D in demonstrating both the performance of a country's economic growth and the competitiveness of foreign markets has once again been highlighted by globalization and efforts to integrate international goods, services, and factor markets. (Saygılı, 2003)

The knowledge and experience that R&D activities ultimately produce have a significant impact on a company's profitability level and also help to produce products that are extremely competitive. R&D is not just about technological advancement and the resulting rise in production; it also plays a significant role in the development of new technologies in advanced economies, such as design or learn-by-doing. (Guellec & Pottelsberghe, 2001)

This section analyzes some important theoretical frameworks that explain how technological advancement is based on R&D expenditures. It is acknowledged that Romer's seminal essay from 1990 served as the foundation for the literature in this area.

2.2.1 Romer model (1990)

The R&D actions are foundation of Romer Model and the person fund recruited in R&D secture and ingoing product or production techniques produced by the identical sector constitute the general framework of this model. Achieving a sustained growth ratio in maxi-term depends on amount of qualified workforce such as scientists, researchers and technical staff changed to R&D secture by economy. Upward of inputs of human capital which make up in an economy and the more the economy allocates these resources to the R&D sector, greater growth in this economy will be. In this kind of internal growth theories, ingoing thoughts gained through profitable R&D investments and the resulting knowledge perform a substantial role. (Romer, 1990)

Romer, the creator of the R&D essential growth pattern, gave economic growth new color in 1986 with his publication, "Increasing Returns and Long-Run Growth," which

is regarded as the first internal growth model. Romer considers R&D to be his most crucial project. Romer's work is based on the human capital in R&D units and the new goods or production techniques that are produced as a result of these units' operations. (Romer, 1986)

After conducting his research in 1986, Romer described R&D as the engine of growth, and he first introduced the crucial economic growth pattern under the name "Endogenous Technological Change" in 1990 (Jones, 1998). Technology advancement is viewed as the primary driver of economic growth in Romer's study. Conscious individual behaviors result from market incentives provided by governments, and these incentives spur technological advancement. Romer makes a distinction between novel production methods developed through R&D and innovations and conventional production, which can be carried out repeatedly without incurring fixed costs. (Romer, 1990)

Romer highlighted two instances of current technological development. The first is an economic feature that boosts productivity and promotes economic growth, and the second is that technological advancement is accomplished through the state's or the unit of production's economic decision-making processes with the resource direction that is made clear. Romer contends that investing a growing amount of private capital in R&D units can lead to sustainable growth. Romer claims that the use of technology is non-competitive and somewhat constrained. The companies operate from the weak position of the price buyer in ideal competition conditions to the companies that have technological monopoly power in the monopolistic competition market thanks to the power provided by the technologies that they develop. (Romer, 1990)

As a result, in Romer's model, capital accumulation is insufficient to support economic growth. The factors that will end the disparities in global development are innovation, knowledge, and technological change. The engine of economic growth is the R&D sector, which knowledge, technological advancement, and entrepreneurs have created. Romer, who made significant contributions to the literature in a variety of ways, said that R&D is still an important factor in the creation of innovations and that its efficiency rate has a direct impact on the innovation process. (Romer, 1990)

Romer's theory of economic growth that favors technology is predicated on three key facts. These are listed below: (Romer, 1990)

- Due to technological advancements, feedstock promotion is now possible during the manufacturing stage as well. Products created as a result of usage form the basis of economic growth, and technology-enhanced sustained capital saving is at the cutting edge. Additionally, throughput remains under the influence of technology, but fixed workforce costs increase.
- But while academicians do technological growing to investigate incoming information outside their areas of advantage, businesses or contractors who want to maintain their advantages typically do technological growing. Therefore, technology is an evolving and endogenous change.
- Acquiring ongoing knowledge has a one-time book value. The repeated promotion of the generated information has no intrinsic value. This is argued to be a characteristic of technology.

The assumptions of Romer's economic growth model with a technology focus are as follows, in addition to these three elements:(Romer, 1990)

- Both the labor force and the current population will stay stable.
- Both the amount of person funding that is recruited by inhabitants and the portion that is supplied to the market are fixed.
- The capital sector should be given the products that are not consumed from the consumption sector.
- Only human capital is used to create new knowledge and designs supported by technology. Capital or unskilled labor are not involved currently.
- The capital goods are not worn out.

2.2.2 Jones model as a semi-endogenous growth model

The amount of person funds employed in the R&D segment is inversely correlated with the maximum run stable growth proportion in the Romer Pattern. This impact has some sort of scale effect. Jones presented a model that eliminates scale impacts in two studies he published in 1995. Jones explains how removing scale impacts causes the anticipated growth impacts from internal growth models based on R&D to disappear or decrease. (Jones, 1995a; 1995b)

Jones claims that the structure of first generation R&D principal growth models makes the scale impact empirically problematic. Jones (1995) and Kortum (1997) both mention this. According to Jones' study, the number of academics and engineers employed overall during the post-second world war period has increased significantly. The growth rates of the nation's income and Total Factor Productivity (TFP) remained constant, or at least did not change. (Lin, 2001; Jones, 2005)

The findings of policy inefficiency have led Jones to another significant conclusion. The growing proportion of so-called per capita income is proportional to the labor growth proportion when the scale impact is taken out of this model. On the one hand, it is possible to claim that growth is internal because it is the result of deliberate R&D choices made by private companies in response to market incentives. On the other hand, it is external because it is unlikely that public policies will be able to control the direction of stabilized development. (Jones, 1997)

Romer's current model was somewhat improved by Jones' analysis of the impact of R&D on economic growth patterns in industrialized nations in 1995. A non-predictable continuation of R&D does not have an impact on economic growth, according to pattern.

In 1995, Jones asserted that the model's scale effects were established. He proposed that when scale effects vanish, the anticipated growth effects of R&D's crucial internal growth patterns vanish or weaken. (Jones, 1995)

He created a model of semi-intrinsic growth. The study looked at the growth rates of the total number of scientists and engineers from France, Germany, Japan, and the United States of America as well as some consideration of thrift growth rates in time series to demonstrate the validity of R&D-based growth models. Scientists and engineers were employed in the economy after the Second World War, according to Jones' research, which examined economies, but there was no increase in national income or total factor productivity growth rates. (Jones, 1995)

The growing proportion of revenue per person is proportional to the labor force growth proportion when the scale effect is taken out of the model. Products of deliberate R&D decisions argue that growth is external due to market incentives of private firms because public policies cannot control internal, balanced development. (Jones, 1997)

The policy suggests ineffectiveness as a result.

2.2.3 Grossman and Helpman's model

The growth pattern proposed by Grossman and Helpman, which depends on technological advancements, connects growth to openness and international trade. Underdeveloped nations that lack the resources to invest in R&D will be able to obtain the technologies they need by transferring technologies from developed nations as long as their openness rates are maintained. Technology transfer won't happen on its own, though. The incentives provided by developing nations for technology transfers and the ease with which they provide convenience to multinational corporations play a significant role in making this happen. (Grossman & Helpman, 1991)

Grossman and Helpman contend that protectionist policies are detrimental to economic growth, whether in developed nations that invest enough money in R&D or in developing nations. If developed nations adopt protectionist policies, spending will shift from R&D to consumer goods, which will prevent long-term growth rates because it will be impossible to use money to create information. In this way, the qualified labor force in the economy will move to the manufacturing industry as a result of the implementation of protective policies, which will reduce technological innovations, the catalyst for economic growth. (Grossman & Helpman, 1994)

Under two headings, Grossman and Helpman look into the growth model based on technological advancements. The first of these is the growth effects of technological advancements brought on by the continuation of product variety, and the second is the effects of growth and public awareness. Businesses earn monopolistic rents in the model based on the continuation of the product assortment. (Eaton & Kortum, 2006) Investments in R&D allow businesses to create cutting-edge products that earn monopolistic rents and non-competitive goods that can be used by all businesses. Romer's 1990 Model served as the foundation for much of the quality of information as public property.

The following are the model's hypotheses: The potential for the development of incoming goods is limitless, and the amount of money required for innovation is constant. There are no diminishing returns to scale in the information manufacturing industry. The cost of manufactured goods is determined by wage rates. The free entry condition sets the wage rates. The expectation of profits by the firms will determine how many businesses will be present in the market. Prices and source distribution are

solved for in the scenario of static equilibrium on the premise that firm value and product variety are both constant.

The Romer (1990) Model was expanded upon by Grossman and Helpman's second model, which included industrial R&D gains and was predicated on the notion that knowledge is a public good. There are thus two distinct outcomes of R&D activities. Each R&D project begins by creating a design for an ongoing product. The creator of this contemporary design benefits from a monopoly profit. Second, every R&D project advances the general capital stock (K_n) that already exists.

Future generations can use the opinions and techniques that are depicted in this capital stock. The ability to defer current consumption to future periods and the variety of product diversity influence the growth of technological innovations, the amount of human capital in the economy, and the efficiency rate in R&D activities.

The variety of labor resources increases the total amount of labor employed in the industry, which increases the total amount of labor that can be used by the innovation manufacturing sector, allowing for the creation of new technologies.

Models by Gene M. Grossman and Elhanan Helpman, which were published in 1989, 1990, and 1991, are among those that made a significant contribution to the growth strategy based on new discoveries and technological advancements. According to Grossman and Helpman's models, technological innovations that come about as a result of economic units' deliberate behavior are internal.

They think that technological advances' increases in productivity are what fuel economic expansion. They link the phenomenon of growth, foreign trade, and trade policies in Grossman and Helpman's work and model with the various and novel products produced by each nation. The R&D sector ensures economic growth by boosting the economy's competitiveness by making use of the benefits of international trade.

They contend that countries with insufficient investments in R&D and hedges will benefit most from increasing their share of global trade and acquiring the necessary technologies through developed technology transfers made possible by free trade policies. In the long run, economic growth will also come from productivity gains brought on by technological advancements. (Grossman & Helpman, 1991)

Grossman and Helpman (1989) assert that new products produced as a result of R&D and technological advancements will also profit from the opportunities provided by international trade, giving nations a competitive advantage. This will open the door for economic development in countries that have a competitive advantage.

Grossman and Helpman assert that conservative strategies like tariffs and quotas will stop countries' growth without making any distinctions between them. The protectionist policies of nations that fund R&D units adequately but shift their spending to consumer goods may have a negative impact on those nations' long-term growth rates.

Because of the activities that will lay the foundation for adding value by shifting spending from R&D to consumer goods, protective policies will cause growth to stall. Trade liberalization encourages the employment of qualified workers in the R&D sector in sophisticated countries while facilitating access to information through technology transfer in less developed countries. (Grossman & Helpman, 1990, 1994)

The "Dynamic Comparative Advantage" model is discussed in "Innovation and Growth in the Global Economy" by G. Grossman and E. Helpman. The primary factor affecting the trade structure in this model is the quantity of differentiated product designs. In other words, the structure of international trade varies according to the quantity of new discoveries made as a result of R&D studies and hedges conducted by nations. The phenomenon of innovation, which raises the diversity and quality of intermediate goods as a result of R&D actions, is the weld of economic growth in this model where innovation is internalized.

The accumulation of knowledge capital is recognized as a key component of technological development in Grossman and Helpman's model of economic growth: Authors who view technology as a good have developed two types of good: 1. They saw technology as a non-disruptive commodity; 2. Technology is a product that can be partially prevented (easily intercepted by patent, copyright, etc.). As a result, technology is an instrument of knowledge capital. (Grossman & Helpman, 1990)

The model was built under the assumption that savings were used for research and development. Reduce production costs and create new products are R&D's two primary goals. R&D results in technological advancement, which leads to monopoly profit (excessive profit).

As a result, the market has a monopoly structure. Although there will be more global competition, monopoly profits will decline and there will be fewer technological advancements (since competition forces businesses to create new inventions). Profit expectations and rates are what control how many businesses enter this market.

The products available on the market can't completely replace one another. Conditions for entering the market determine wage levels. As a result of the wage rate, the product prices develop. (Grossman and Helpman, 1991) A small country's population can increase because of technological advancements and international trade. Large nations devote more funds to research and development. Growth and technological advancements will occur more quickly. Therefore, countries with more skilled labor experience faster growth. Due to differences in R&D investments and technological development, comparative advantage shapes the structure of international trade.

This analysis suggests that while companies engage in international trade, countries do not. Three significant criticisms of the model are possible; First, they discuss how reducing global competition results in lower monopoly profits and fewer technological advancements, whereas increasing global competition results in more technological advancements. Second, they adopted the theory of comparative advantage among nations, but businesses no longer trade. Thirdly, it is incorrect to simultaneously set prices on the capital, factor, and product markets.

2.2.4 Aghion and Howitt model

The incoming Schumpeterian "creative destruction" model created by Aghion and Howitt is another R&D-based growth pattern. (Aghion & Howitt 1992) According to Schumpeter, the engine of the capitalist system and its primary driving force are new markets, new manufacturing or transportation techniques, and new consumer goods. The old economic structure is continuously destroyed as a result of this process, and a new one is continuously created. The fundamental truth of capitalism is the process of creative destruction. (Alcoufe & Kuhn, 2004; Schumpeter, 1970)

The innovations created as a result of R&D activities and these innovations indicate a progressive improvement in product quality in the Aghion-Howitt model. Obsolete innovation or innovation of an ongoing invention is the main element of quality improvement initiatives that take the form of vertical innovation. (Aghion & Howitt, 1998)

A new invention's obsolescence or creative destruction has two effects. The first is that it acknowledges a negative correlation between present-day and upcoming R&D activities. Second, even though current R&D activities generate positive externalities that will benefit future R&D endeavors, they may also have unfavorable effects on producers. According to this model's interpretation of Schumpeter, individual innovation has a sufficient impact on the entire economy. The time span covered is in between two successful innovations. The novelty continuum's indiscriminate disposition causes the interval between each successful innovation to be random. R&D activity levels in the two successful innovation periods, however, can have a deterministic relationship.

Due to two effects, there is a negative correlation between the R&D amount made in the first period and the R&D amount anticipated to be made in the following period. The first is the sense of asymmetrical conflict. Initial R&D efforts are based on the level of monopolistic rent that is anticipated to be attained in the future. Until a new technological advancement is made, these rents will remain in effect. As a result, the amount of novelty that may be possible in the subsequent period is backward interested in the present value of expected rent. Second, the R&D and manufacturing sectors can benefit from the overall equilibrium impact of changes in the wages of skilled labor (Diao et al., 1999)

The two R&D periods' functional relationship results in a stable and stable state equilibrium for the economy. The skilled labor pool is evenly distributed between the R&D and manufacturing sectors in this equilibrium, and the GDP is randomly rising. An innovator who has been successful in the past secures a patent that grants him monopolistic status in the market for intermediate goods. Patents are said to continue forever. Although patent rights are unaffected by time, monopoly power lasts until further technological advancements. The interval between the two technological innovations is chosen at random, and the model is unable to forecast when a technologically superior and higher-quality innovation will take place. Every market, with the exception of the intermediate sector, is fiercely competitive. (Aghion et al., 2001)

The model has a sizable impact on spreading across periods. A technological advancement increases effectiveness without permanently diminishing its impact. Each innovation guarantees a creative impact with the goal of monopoly profit.

However, it also gets rid of the rents that came from the earlier innovation. As a result, the profits from the remaining R&D activities and patent competition are reduced. (Aghion & Howitt, 2004)

Philippe Aghion and Peter Howitt conducted "Model of Growth Through Creative Destruction" in 1992 and "Endogenous Growth Theory" in 1998, both of which were motivated by Schumpeter's notion of creative destruction. With the help of these studies, they, like Schumpeter, created an internal growth model by looking at how technological innovations brought about by R&D activities impacted economic growth.

The primary competitors in the model are Aghion and Howitt. They created innovations in vertical technology. A technological advancement's effectiveness continuously multiplies its impact. The authors claim that there are two market segments. Research is the first of these sectors, and production is the second.

The production sector aims to produce finished goods, while the research sector aims to produce the intermediate goods needed to produce finished goods. The activities of the search sector lead to inventions and innovations. Rents from the prior innovation are eliminated by every innovation that follows it and by the desire to turn a profit.

Here, new fame is being created to replace outdated goods, which is how growth is based. Innovations developed as a result of R&D activities pave the way for the introduction of new, higher-quality products to the market while also rendering older ones obsolete. Therefore, R&D activities enable the process of creative destruction and lay the foundation for the replacement of the outdated technologies with superior ones. Along with these, the authors propose that because R&D generates positive externalities, the public sector can use it as a tool for economic growth. (Aghion & Howitt, 1992, 1998)

In contrast to other internal models created by vertical technological innovations, Aghion-Howitt's model accepts technological innovations as an internal phenomenon. The innovations created as a result of R&D actions and the goods quality of these innovations show a successive development in the Aghion-Howitt model. The innovation or new invention made as a result of technological advancements in the competitive R&D environment is aging the existing technology or product. This is the

main characteristic of quality improvement efforts in the form of vertical innovation. (Aghion & Howitt, 1998)

Aghion and Howitt contend that it is difficult to adapt to technological advancements brought about by R&D activities. After competing with them, new technologies frequently replace the older ones. Simply put, the diffusion of technology takes time. (Aghion & Howitt, 1992)

The Aghion-Howitt growth model states that growth appears as a chance collection of research-driven innovations that improve quality. Every innovation that takes place raises the standard of a product that already exists, but there is no guarantee that any innovation-related research will be fruitful. Every innovation replaces and eliminates the previous technology. More obviously, consumers do not use old technology when new technology is developed. This brings up the idea of "creative destruction" proposed by Schumpeter. The New Schumpeterian Growth Model was developed by Aghion-Howitt for this reason.

The market research and production are divided into two sectors in accordance with this model. A production sector is responsible for creating finished goods, and a research sector develops intermediate outputs that are used in the production of finished goods. Innovations and innovations result from R&D activities. These inventions by businesses acting profitably in the past eliminate rents acquired from those inventions. The use of newly produced goods to replace the outdated ones in this situation is the engine of growth. The reason for this is that new and improved products are introduced to the market as a result of innovations brought about by R&D activities. Better people take the place of the ancients. Aghion Howitt (1992, 1998) advises policymakers in this regard that employing R&D as a tool will produce favorable externalities and boost economic growth.

When a research-based innovation materializes, its creator gains monopoly control over the market for intermediate products. Innovations resulting from competition in the research sector lead to the creation of a monopolistic intermediate products sector. According to this model, when a nation innovates, its productivity level elevates to the level of the most cutting-edge technology and establishes the upper bound. The technology of the innovative nations advances if the country maintains its current level of innovation. The non-innovating nation has outdated technology. In this context, the

gap between nations that are unable to cross the technological frontier and those that can widens in comparison to those that can.

Technology innovation is seen by Aghion-Howitt as an internal phenomenon. This model differs from other internal growth models in that product quality is improved by vertical technological innovation. This model states that the innovations produced by R&D activities and these innovations exhibit a progressive improvement in product quality. More specifically, the existing technology or product of innovation or invention resulting from technological developments in the competitive R&D sector is the key component of quality improvement efforts in the form of vertical innovation. (Aghion & Howitt, 1992)

However, it is not simple to adapt to these technological advancements brought about by R&D activities. New technologies primarily compete with older ones. They frequently win and balance more senior ones. This is a continuum of dating consumption. (Aghion & Howitt, 1992) According to Aghion and Howitt, each technology developed following each R&D activity has an exponentially growing impact on subsequent products. New products will result from the research, and the subsequent research will be made possible by the new products. A situation is followed by another one on top of it. R&D initiatives for innovation can be viewed as the engine of the economy in this context.

By introducing a Schumpeterian perspective to internal growth theory, Aghion and Howitt created a two-sector model. In a model with production and research sectors, the production sector produces the final product, whereas the research sector focuses on creating the intermediate product that is used to create the final product.

The standard of outputs is achieved in this model by "Vertical Technological Innovations". This model's source of growth, vertical technological innovations in the competitive R&D sector, sets it apart from other internal growth models.

R&D-driven innovations lead to the introduction of more new products to the market and the obsolescence of older ones. At the conclusion of this process, better and new products replace the outdated ones, and Schumpeter calls this "creative destruction".

New consumer goods, innovative production or transportation techniques, and fresh markets, in Schumpeter's view, are the driving forces behind the capitalist system. The old economic structure is destroyed and the new one is constantly renewed by this

process. The necessity of capitalism is this process of creative destruction. According to the model, the quantity of extensive R&D activities determines the rate of economic growth and that each individual R&D effort has a significant impact on the overall economy. The Schumpeterian creative demolition model's two most crucial components are technological innovations that help improve product quality and a patent system that fosters dynamism by protecting these innovations.

"Vertical Technological Innovations" in the R&D sector are a source of growth, claim Philippe Aghion and Peter Howitt. (Aghion & Howitt, 1992). New products are substituted for the obsolete ones. So, the "creative destruction" process is effective. (Gürak, 2006) Aghion-Howitt's model of product competitiveness has a significant place in internal growth models.

Three fundamental characteristics define the Aghion and Howitt model. The first is improvement in the flawed competition system. The technological process is formed through the investments of the R&D sector of the companies that are drawn to the monopolistic profits under the imperfect competition market, even though it is realized in competitive market-based growth models with the effect of spreading. The quality of the invention's intermediate goods is improving at a higher rate as the R&D sector expands more quickly. According to this presumption, the inventor who has monopoly power will continue to dominate the market for a year (or until the patent expires).

The idea of creative destruction is the second. Due to the destructive nature of technological advancements, products consequently have a life cycle, after which they are discarded and replaced by new ones. A high rate of profit is guaranteed by the producer's monopolistic position. The primary driver of growth is this. And finally, discontinuity. The technological framework is broken up. Specialized labor spurs technological development and growth. (Gürak, 2006)

The researchers claim that it is possible to condense the economic growth model's components and detractors into the following list:

Technological advancements are a source of growth as well as internal. Specialized labor is created by new technologies.

- Growth rate
- Number of innovations

- Number of qualified workers
- factors related to R&D productivity

As a result, it falls short of adequately explaining the disparities in growth between nations.

Technological advancements are made possible by the value competitive businesses place on "R&D".

- The GDP growth rate fluctuates.
- The model consists of three sectors:
 - the research sector,
 - the search-invention sector (where scientific invention and technological innovation emerge),
 - the consumer goods sector.

The marginal utility of consumption has been held constant in a significant case. (Any good after a certain point cannot continue to be stable.) The preferences are the same throughout society. (Gürak, 2006)

2.2.5 Acemoğlu and Zilibotti model

One model for analyzing income differences between advanced and forward-thinking countries, the Acemoglu-Zilibotti Model, claims that these differences are brought about by developing countries' selection of unsuitable technologies. (Acemoglu and Zilibotti, 2001)

Unprecedented technologies are created primarily to meet the needs of industrialized, wealthy, developed countries, so when they are applied to developing, underdeveloped nations, they do not have the same effects. According to this model, there are two different types of economies: North and South. Northern economies have a cutting-edge setup. There is no ongoing technological creation taking place in the South. The economies of the South are, however, adjusting to the new technologies created by the North. Southern nations do not carry out the legal arrangements for the preservation of spiritual ownership rights. The economy is divided into three sectors: the sector of finished goods, the sector of intermediate goods, and the sector of machinery. (Acemoglu and Zilibotti, 2001)

Machinery sector businesses are divided into two categories: innovative (North) and copycat (South). Innovative companies that develop ongoing technology in the North are able to charge a rent because the Northern economies offer strong patent protection. There is no R&D activity in the South because intellectual property rights are not protected. Machine makers in the South duplicate Northern designs for a low fixed cost. (Basu & Weil, 1998)

As a result, businesses in the South use equipment created in the North. The labor force's skill level is relatively low in the South. According to this model, the output per worker in the economies of the South is lower than the output per worker in the North. Even if both groups of economies employ the same technology, this conclusion is still true. A variety of technologies developed with consideration for the fundamental traits of the Northern economies are used in Southern economies. However, when used in the South, these technologies perform less than at their best.

The difference in productivity between the North and the South is brought on by incompatibility in technology. These North-developed technologies are incompatible with the skills of the labor force in the underdeveloped and developing economies. Different countries have different levels of development due to differences in their economic structures.

It was acknowledged that appropriate innovation and technology were required to improve market conditions and economic expansion. The Acemoglu-Zilibotti Model contends that developing countries' inability to select the right technology is the cause of the income gap between them and developed nations. (Acemoğlu & Zilibotti, 1999)

The issue is that new products developed in developing countries do not have the same positive impact as innovations made in developed countries because they are designed to meet the needs of developed countries. Two countries—North and South—represent two distinct economies in Acemolu and Zilibotti's model. The area of technology development is where these two nations diverge most. A nation called North creates cutting-edge goods and technology. In the name of innovation, the South is a nonproductive nation that adopts newly developed technologies from the North into its own system. (Acemoğlu & Zilibotti, 2001)

In the Northern nation, patent intellectual property rights are protected; however, there is no similar law in the Southern nation. The model accepted three sectors. These three

industries are machinery, intermediate goods, and final products. Due to the Northern country's protection of patent rights, the proliferation of patents by innovative businesses spurs growth by raising the economic surplus.

In the South, there is no legislation governing patent protection. In businesses, they are less likely to design than to copy machines created in the North at a set price in their own nation. They precisely implement the technology they observe. According to the model, the South will produce less than the North in terms of output per worker. Even when the same technology is employed, this premise still holds true.

Because they are in line with the ratio's requirements, the technologies created for the Northern economy do not function effectively in the Southern economy. This demonstrates the disparity in technology between the two nations. Because of these differences in labor force capabilities, the technologies they transfer from developing countries to developing countries do not produce the expected efficiency. The right technology should be discovered by economies. (Acemoglu & Zilibotti, 2001)

2.2.6 Schumpeter model

Joseph Alois Schumpeter, who lived from 1883 to 1950, was a well-known thinker who produced works in numerous fields. By creating various strategies, he expressed the dynamics of the capitalist economic system. For instance, some of them are monopolization, innovation, economic growth, business cycles, unemployment, savings, income distribution, political economy, and economic sociology. His numerous writings in the areas of politics, sociology, and economics can all be evaluated. It can be argued that Schumpeter has an elitist viewpoint when considering her theories in the social, economic, and political spheres as a whole.

These opinions of Schumpeter regarding economic analysis demonstrate that she operated outside of Neoclassical economics. He asserted that the dynamic imbalance caused by the creative entrepreneur is the norm of a sound economy and is at the heart of economic theory and practice (Drucker, 1984) rather than balancing and optimizing. due to the dynamic processes that underpin economic life, which are constantly changing. In his economic analysis, Schumpeter attempted to find the balance within the imbalance because for him, the imbalance had a positive meaning. At this point, he claimed that the extreme rationality-based mathematical models of Neo-Classical economics were insufficient to adequately explain economic analysis.

Schumpeter was also against the way that capital and profit were viewed in neo-classical economics. Instead of seeing capital as a tool for production, Schumpeter saw it as the purchasing power that entrepreneurs need to innovate. The entrepreneur will have the chance to access the production tools thanks to this purchasing power, which is owned by bank money (credit). At this point, Schumpeter claimed that innovation was a key force behind the emergence of economic growth.

Schumpeter's entrepreneurial model has an innovative and dynamic nature that constantly pursues the new, whereas Weber's entrepreneurial profile is static and expresses an ascetic lifestyle that is extremely remote from worldly goods. In terms of economic growth and development, Schumpeter's approaches to innovation have provided new opportunities and perspectives for all nations.

Schumpeter asserts that a firm has a life cycle. This phase starts with the creation of a brand-new, improved, or less expensive product and ends with the entry of new rivals. When competitors are new, businesses are at their most profitable. In this model, profit holds a key position.

This model holds that neither progress nor profit can occur without the other. (Schumpeter, 1939) 'Creative destruction' is how he refers to this process. This procedure is inventive in that it fosters technological innovation, but it is destructive in that it eliminates businesses that can't keep up with advancements in technology.

2.3 R&D

Research and development (R&D) has been emphasized as a significant factor in economic growth in a great deal of empirical and theoretical work. Through its beneficial impact on innovation and total factor productivity, R&D spending is likely to promote growth (Romer, 1990; Lucas, 1988). As Grossman and Helpman (1994) point out, technological advancements brought about by industrial innovation have long been the main driver of steadily rising living standards in the industrialized world. When a company invests in R&D, it is anticipated that new concepts, intermediate products, cost-cutting techniques, and finished consumer goods will be created, enhancing the company's productivity and profitability. R&D has public benefits as well as positive spillovers within and between businesses, industries, and geographical areas. Due to the non-rival nature of knowledge created through R&D, businesses can

profit from the R&D expenditure of other businesses, even if they are located in different industries or geographical areas (Arrow, 1962; Aghion and Howitt, 1992).

Between countries, there is a significant disparity in both R&D activity and economic growth. For a chosen group of countries, data from the World Bank's Table 1 shows average R&D spending as a percentage of Gross Domestic Product (GDP) for the years 2000–2010, 2010–2020, and 2020.

Table 2.1 R&D expenditure as a percentage of GDP

	2000- 2010	2010- 2020
Korea, Rep.	2.63	4.09
Singapore	2.11	1.98
Brazil	1.05	1.2
Russian Federation	1.15	1.06
Türkiye	1.34	0.91
Thailand	0.23	0.74
India	0.78	0.71
Chile	0.34	0.36
Colombia	0.17	0.27
Indonesia	0.07	0.22
Peru	0.12	0.11

Six countries conducted more R&D in 2020–2010 than in 2000–2010, but there is no single global trend in R&D spending. Comparatively, South Korea appears to invest significantly in R&D; however, only four of the selected nations—South Korea, Singapore, Brazil, and the Russian Federation—have R&D expenditures that are above 1%. Thailand's investment level has clearly increased. Türkiye is one of the nations whose share of investments has increased over the past ten years.

There are at least four reasons for the apparent large degree of heterogeneity among the nations. Most importantly, there is a long-term relationship between R&D and economic growth. According to Griliches and Lichtenberg (1984), fluctuations in the level of capacity utilization in industry account for a large portion of the short-run variation in output.

Second, investing in R&D is an investment in knowledge, a durable good. As a result, rather than just current-year investment, the stock of knowledge is the proper input to the production function (Romer 1986, 1990). Third, since knowledge cannot typically

be contained within national boundaries, firms in one nation profit from the R&D that is carried out abroad (Coe and Helpman, 1995). Finally, the relationships between R&D, innovation, and growth can be significantly influenced by the general level of economic development in the nation, as well as by its institutions and even attitudes toward risk-taking and entrepreneurship.

This study makes an effort to quantify the effects that R&D spending has on economic growth in light of the significant role that it plays in development over the long term. For policymakers, it's critical to comprehend the part R&D plays in determining productivity and, in turn, economic growth.

Cincera (2005) pointed out that in order to find effective science and technology policies that could boost productivity and competitiveness across firms and industrial sectors, it is important to investigate the impact of R&D spillovers.

2.3.1 Theory on the impact of R&D

R&D has been added as a key factor in the modification of Solow's (1956) neoclassical growth model, which treats productivity, capital accumulation, and population growth as the main sources of economic growth. The notion that increased R&D spending results in increased productivity was first put forth by Griliches in 1979.

According to Romer's (1986) endogenous growth model, firms' R&D expenditures increase overall output because private R&D generates spillover effects by adding to the public knowledge base. Because technological advancement is the result of deliberate economic investment and sustained growth is not possible without R&D spillovers, R&D expenditures are essential to economic growth (Griliches, 1992).

Their analysis of growth theory and endogenous innovation makes a compelling case that advancements in technology have been the primary force behind global growth, noting that "most technological progress requires, at least at some stage, an intentional investment of profit-seeking firms or entrepreneurs" (Grossman and Helpman, 1994). According to this perspective, industrial innovation brought about by R&D expenditures serves as the main driver of economic growth.

Grossman and Helpman (1994) assert that a significant financial outlay is necessary to reap the rewards of the advancement of scientific ideas. If there is a chance for businesses to increase profits, they will be motivated to invest in R&D. So, if the

profitability of R&D is increased (for instance, through investment-promoting policy), more investment will flow into private-sector R&D, which will speed up innovation and lead to higher productivity.

2.3.2 Empirical evidence on the impact of R&D

Based on the unit or level of analysis, empirical studies on the effects of R&D can be divided into four categories: company, industry, region, and country. Beginning with the early work of Mansfield (1965) and Griliches (1980a), firm level analyses concentrate on the effect a firm's R&D spending has on its own productivity. The R&D expenditure of one firm's spillovers to other firms and industries is also measured in some of these analyses. Studies at the industry level (Griliches, 1973, 1980b) also examine the relationship between R&D in one industry and increased productivity in both that industry and other industries. Empirical studies at the regional (Bronzini and Piselli, 2006) or national (Griliches, 1964; Nadiri, 1980a, 1980b) level examine how R&D spending affects productivity and growth in the region or nation where it originates. Some studies also look for spillover effects to other regions or nations. The more recent trend of regional studies is followed by the current study.

Coe and Helpman (1995) found that while domestic R&D is linked to higher productivity and economic growth, foreign "knowledge stocks" are also essential for explaining TFP. This is in relation to R&D spillovers across regions and countries. They contend that international R&D could boost domestic productivity directly by fostering the creation of novel technologies and procedures and indirectly by fostering the importation of goods and services. They offer empirical evidence for these claims using data from 21 OECD nations between 1971 and 1990. Frantzen (2000) also conducted a cross-section analysis of OECD nations. He discovered that R&D is more significant in G7 countries than in economically smaller countries, and that economic growth in those countries is closely correlated with innovation, which is influenced by both domestic and international R&D. In their regional study from 2006, Bronzini and Piselli also discovered the significance of spatial spillovers.

Economic growth theory has been extensively studied in the past and present. Many academic studies have examined one or more country groups in the past research. While some academic studies concentrated on the number of patents, R&D spending, and economic growth, other studies examined the long- and short-term relationships

between these variables over various time periods. Below is a review of many of the empirical studies that were mentioned in this study.

Using panel data analysis, Lichtenberg (1993) investigated the relationship between R&D expenditures financed by the public and private sectors and economic growth in a study of 74 countries spanning the years 1964–1989. The study's conclusions are as follows: When R&D expenditures are financed by the public sector, there is no effect on economic growth and, in rare circumstances, a negative effect; when private sector financing is used, it has been observed that there is a positive and significant relationship between growth and productivity (Lichtenberg, 1993).

Using Goel and Ram's (1994) Cross-Section Analysis, the impact of R&D spending on economic growth was examined using real income, capital, and labor data from 52 countries, including 18 developing and 34 underdeveloped nations, for the years 1960 to 1985. Multiple regression was used to test the analysis. The study's findings revealed that only high-income nations experience a correlation between R&D spending and economic growth. However, it is unknown whether there is a causal relationship between R&D expenditures and economic growth, or vice versa.

Using panel data analysis and two distinct expenditures—private and public sector—Park (1995) examined the relationship between R&D investments and growth in production in his study, which covered the years 1970–1987 and involved 10 OECD countries. According to the study's findings, local private sector R&D investments were found to be a more significant determinant factor for the rise in both local and foreign factor productivity than public sector R&D investments. Furthermore, it was discovered in the study that public spending had a secondary impact on productivity growth by encouraging private sector investments in foreign public R&D projects.

In his investigation into the link between privately and publicly financed R&D spending and economic growth, Griliches (1998) focused on the US economy. The conclusions drawn from the results show that a 10% increase in R&D spending results in a 7% increase in real income and that R&D spending supported by the private sector has a greater impact on economic growth than R&D spending supported by the public sector.

Using panel data analysis, Freire-Serén (2001) investigated the relationship between R&D spending and economic growth in a study of 21 OECD nations spanning the

years 1965–1990. The study's findings indicate that there is a very strong positive relationship between economic growth and R&D spending, and that, when taking into account the factors defining innovation technology, the elasticity of R&D spending, a 1% increase in R&D spending increases real GDP by 0.08%. It was discovered to be very nearly 1.

Sylwester (2001) used panel data analysis to examine the relationship between R&D spending and economic growth for 20 OECD countries, 7 of which were G7 nations, for the years 1981 to 1996. Although it is evident that there is a relationship between R&D spending and economic growth, there is no relationship for 20 OECD countries.

In his research on 10 OECD countries from 1971 to 1995, Zachariadis (2004) looked at the impact of rising R&D spending on economic growth. The model used in this study calculates the correlation between R&D intensity and growth in output and productivity. The study came to the conclusion that higher R&D spending had a positive impact on both the growth rate of productivity and the level of output.

In a study covering the years 1994–2003 of 8 Far East Asian countries, Yanyun and Mingquian (2004) used the Panel data method to examine the long-term relationship between R&D expenditures and economic growth. The study's findings revealed a bidirectional relationship between the two variables, with R&D spending having a favorable impact on economic growth. It was emphasized that these nations should prioritize R&D investments and steady economic growth.

Falk (2007) used dynamic panel data analysis to look at the relationship between high-tech R&D investments and per capita income in a study of 15 OECD nations from 1970 to 2004. The study's findings indicate that rising R&D spending and investments in advanced technology R&D have a positive impact on per capita income.

A cross-country production model was established and autoregressive and random walk models were used to learn the relationship between total R&D activities and growth in Wang's study of 30 countries, of which 23 are OECD countries and 7 are non-OECD members. He noted that nations with effective R&D spending experience higher economic growth.

Using Panel Data Analysis, Wang et al. (2013) demonstrate that this relationship is covered in more detail in the study that examines the relationship between R&D expenditures and economic growth for the 23 OECD countries and Taiwan over the

period 1991–2006. The study's empirical results demonstrate a positive relationship between R&D spending and economic expansion. Real income per capita has been found to be strongly and favorably impacted by high-tech industrial R&D expenditures. In contrast, when middle-income countries are the only ones taken into account, R&D spending across all sectors will have a significant negative impact on GDP.

Goel et al. (2008) investigated whether federal R&D expenditures and non-federal R&D expenditures have a long-term relationship on economic growth using defense R&D using the ARDL (distributed lag autoregressive) method in a study covering the 1953–2000 period of the US economy. The study's findings revealed that there is a much stronger correlation between federal R&D spending and economic growth than there is between non-federal R&D spending and economic growth. Additionally, they came to the conclusion from the research that another variable—defense R&D spending—has a greater impact than non-defense R&D spending and that it has a greater impact on economic growth.

In their study of 30 developing countries, which they took as a sample, and which they covered the period of 2000–2006, Samimi and Alerasoul (2009) used panel data analysis to examine the impact of R&D expenditures on the economic growth of developing countries as well as the relationship between the two variables. Including R&D costs; auxiliary variables are used, such as the proportion of public research spending in GDP, the number of researchers per million people, and the scientific output of nations. The study's findings indicate that there is no correlation between R&D spending and economic growth that is both significant and positive. They made the case that R&D activities should be increased in these nations, citing the low proportion of developing countries' R&D expenditures as the cause.

The relationship between innovation performance as measured by per capita R&D expenditure and the Global Competitiveness Index in 11 Central and Eastern European nations is examined by Kiselakova et al. (2018). They claimed that raising R&D spending can significantly help countries become more competitive, which will lead to growth.

The factors that affect economic growth and competitiveness in the Czech Republic, Hungary, Poland, Slovakia, and Romania were studied by Simionescu et al. in 2017. The main findings indicate that R&D spending has a positive impact in Romania,

Hungary, and the Czech Republic, while foreign direct investment promotes economic growth and competitiveness in all nations with the exception of Slovakia.



3. DATA AND METHODOLOGY

3.1 Dataset

This study aims to analyze the relationship between economic growth and R&D spending in a total of 11 countries, including the fragile five and troubled ten, which are classified by Morgan Stanley as having fragile economies. Using annual data from 11 countries (Brazil, Chile, Colombia, Indonesia, India, Republic of Korea, Peru, Russian Federation, Singapore, Thailand, and Türkiye).

We utilize the real gross domestic product (GDP) per capita as the dependent variable. The precise expression of the level of innovation activities is an important factor in empirical research on the impact of economic growth rate. The most commonly used data on innovative activities are the share of research and development expenditure in GDP. This approach is highly acceptable because it is suitable for quantitative and qualitative analysis. Hence, we also utilize the R&D expenditures as a ratio of GDP as a dependent variable. Gross capital formation (representing domestic investments), labor force, number of researcher and technicians working on research and government spending are used as control variables. We use annual data and the data spans from 2000 to 2020.

Table 3.1 Country List

Brazil	Chile	Colombia	Indonesia
India	Korea,Rep	Russian Federation	Peru
Singapore	Thailand	Türkiye	

Table 3.2 A description of the series used in the analyses

Target Variable	Representational Variable	Symbol	Explanation	Reference
Economic Growth	Real Gross Domestic Product (GDP) Per Capita	<i>GDPPC</i>	GDP per capita based on fixed prices in 2015	World Bank
R&D Expenditures	Share of Research and Development (R&D) expenditures in GDP	<i>RDEXP</i>	It indicates the proportion of GDP that is devoted to research and development (R&D). These expenses cover both capital and ongoing costs incurred by businesses, governments, institutions of higher learning, and private nonprofit organizations.	World Bank
Government Expenditures	General government final consumption expenditure (% of GDP)	<i>GGCE</i>	It includes all government current expenditures for purchases of goods and services (including compensation of employees). It also includes most expenditures on national defense and security, but excludes government military expenditures that are part of government capital formation.	World Bank
Labor	Labor Force (% of Population)	<i>LABOR</i>	The labor force comprises people ages 15 and older who supply labor for the production of goods and services during a specified period. It includes people who are currently employed and people who are unemployed but seeking work as well as first-time job-seekers.	World Bank
Capital Investments	Gross Fixed Capital Formation	<i>INV</i>	Share of gross fixed capital investments in GDP	World Bank
Technicians	Technicians in R&D (per million people)	<i>TECHN</i>	Technicians in R&D and equivalent staff are people whose main tasks require technical knowledge and experience in engineering, physical and life sciences (technicians), or social sciences and humanities (equivalent staff). 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.	World Bank
Researchers	Researchers in R&D (per million people)	<i>RES</i>	Researchers in R&D are professionals engaged in the conception or creation of new knowledge, products, processes, methods, or systems and in the management of the projects concerned. Postgraduate PhD students (ISCED97 level 6) engaged in R&D are included.	World Bank

We employ a multiple regression model with fixed effect (FE) in our study. This strategy is chosen because we decided to examine the impact of a few variables that change over time. The fixed effect model examines the relationship between a

dependent variable and independent and control variables within each individual entity (in our case, the countries that were observed). Each individual determines how independent and control variables will affect the dependent variable (in this case, real gross domestic product (GDP) per capita) based on their unique characteristics.

When using FE, we assume that a factor present in the countries may have an effect on the predictor or outcome variables, and we must take measures to mitigate this.

Another crucial premise of the FE model is that the entity's time-invariant characteristics are specific to it and shouldn't be correlated with those of other entities. Since each entity is unique, its error term and constant (which captures its unique characteristics) shouldn't be correlated with those of the other entities. (Wooldridge, 2002)

FE is not suitable for prediction if the error terms of two entities are correlated. In this situation, random-effect modeling (RE) ought to take the place of the existing model. to evaluate the model's suitability (FE vs. RE). In order to determine whether the FE or the RE model is more appropriate, we utilized the Hausman test, and we decided to utilize the FE model.

3.2 Serial Correlation And Heteroskedasticity

We must address the possibility of serial correlation in the error term and homoskedasticity for time series data. With the Breusch-Godfrey test and the Breusch-Pagan test, we will check for serial correlation and homoskedasticity, respectively, and provide solutions for correction if necessary (Stock & Watson, 2003).

Table 3.3 Results of Breusch-Godfrey/Wooldridge test for serial correlation in panel models

chisq =	df = 6	p-value < 2.2e-
137.14,		16
alternative	serial correlation in	
hypothesis	idiosyncratic errors	

Table 3.4 Results of Breusch-Pagan test		
BP = 47.888	df = 6	p-value = 9.96e-10
Null Hypothesis (H0):	Homoscedasticity is present (the residuals are distributed with equal variance)	

The absence of serial correlation is the null hypothesis for the Breusch-Godfrey test. The test's p-value indicates that we can rule out the null hypothesis and verifies that our error term contains serial correlation.

Similar to how we corrected for heteroskedastic errors, we can use `coeftest()` to correct for serial correlation. In order to obtain a covariance matrix that is consistent with heteroskedasticity, we will use the `vcovHC()` function. However, since we also want to account for autocorrelation, we will specify the `method = "arellano"` option, which accounts for both factors (Stock & Watson, 2003).

We will create these operations when determining the final modeling after determining the model.

3.3 Cross Sectional Dependence

We check for cross sectional dependence using the Pesaran cross sectional dependence test.

Table 3.5 Pesaran CD test for cross-sectional dependence in panels

z = 10.841	p-value < 2.2e-16
alternative hypothesis	cross-sectional dependence

The null hypothesis is that there is no cross-sectional dependence, as we've seen with other tests. However, the p-value indicates that there is cross-sectional dependence and that we must correct it. In general, there are two methods for addressing cross-sectional dependence.

The cross-sectional and serial correlation (SCC) method by Driscoll and Kraay (1998) is preferred for obtaining heteroskedasticity and autocorrelation consistent errors that are also robust to cross-sectional dependence because it addresses the drawbacks of Beck and Katz's PCSE method. Utilizing the `vcovSCC()` function, we can obtain the SCC corrected covariance matrix (Stock & Watson, 2003).

We will decide which model to choose before determining the mods on the outputs. Then we will make the modifications and reach the result.

3.4 Simple Linear Regression

We begin our analysis with a summary of descriptive statistics in Table 3.6 and Table 3.7

Table 3.6 Descriptive statistics and names of variable

Variable	Mean	Std dev	Min	Max
GDPPC	11597	13081	442	66859
RDEXP	1.02	0.97	0.05	4.81
INVGDP	0.25	0.06	0.15	0.42
LABOR	0.48	0.07	0.33	0.62
GGCE	14.31	3.25	6.53	20.79
TECHN	398	299	16	1311
RES	2207	2369	57	8713

Table 3.7 Average of variables by country between 2000-2020

Country	GDPPC	INVGDP	GGCE	RDEXP	TECHN	RES	LABOR
Brazil	7854	0.18	19.32	1.12	599	580	0.48
Chile	11087	0.24	12.83	0.36	275	406	0.45
Colombia	5275	0.21	14.78	0.22	49	73	0.49
India	1218	0.34	10.82	0.75	89	174	0.37
Indonesia	2560	0.3	8.68	0.17	23	237	0.48
Korea, Rep.	23655	0.32	14.18	3.36	872	5422	0.52
Peru	4655	0.21	11.86	0.12	476	701	0.52
Russia	8908	0.22	17.9	1.1	505	3119	0.52
Singapore	44735	0.26	10.24	2.05	459	5946	0.51
Thailand	4637	0.25	15.22	0.46	206	830	0.57
Türkiye	8755	0.27	13.76	0.75	139	935	0.36

The standard deviation exceeds the mean real GDP per capita of 11597. Significant deviation was also present in the explanatory variables (dependent variable and control variables). This might serve as one of the indicators to use the fixed effect model in this paper's upcoming regressions. We assume that each nation has some unique characteristics that have an impact on real GDP growth in various ways.

Table 3.8 represents a correlation matrix between independent variables and predictors. The simple correlation with GDPPC and other predictors is modest. There is not a strong correlation between independent variables, which is good for our future regressions.

Table 3.8 Correlation Matrix

	GDPPC	RDEXP	INVGD	LABOR	GGCE	TECHN	RES
GDPPC	1						
RDEXP	0.54	1					
INVGD	0.17	0.28	1				
LABOR	0.45	0.26	-0.06	1			
GGCE	-0.15	0.1	-0.59	0.008	1		
TECHN	0.08	0.05	0.07	-0.03	0.05	1	
RES	0.008	-0.05	0.06	-0.06	0.18	0.57	1

We start by performing a simple linear regression. The real GDP growth rate is the dependent variable we use. Government final consumption spending, gross fixed capital formation, R&D as a percentage of GDP, labor force, and number of technicians and researchers are the independent variables. In Table 3.9, the regression result is presented.

Table 3.9 Result of OLS

	Estimate	Std. Error	t value	Pr(> t)
Intercept	6.8	0.63	18.33	< 2e-16 ***
log(RDEXP)	-0.15	0.05	9.58	< 2e-16 ***
log(INVGDP)	-0.25	0.29	-1.24	0.197
log(GGCE)	-1.33	0.29	-1.23	0.218
log(LABOR)	-0.43	0.31	8.909	2.44e-16 ***
log(TECHN)	0.33	0.12	2.73	0.007062 **
log(RES)	0.47	0.09	4.824	3.96e-06 ***

The R-squared value, which represents 50.46% of the variance in real GDP per capita, is explained by our regression model. Our regression model's number of variables is taken into account, but adjusted R-Squared has a similar interpretation. The evidence between our independent variable and a dependent variable that accounts for all other variables is essentially what we are looking for. Real GDP growth rate has no relationship with final government consumption expenditures as a percentage of GDP, gross fixed capital formation as a percentage of GDP.

Ceteris paribus applies to the interpretation of the multiple regression coefficients. The p-values for final government consumption expenditures as a percentage of GDP and gross fixed capital formation as a percentage of GDP are particularly high and indicate no significant effect from them. This is the first indication of the regression that we found.

We draw the conclusion that an OLS regression model is ineffective on the basis of two main arguments. The first is that neither the p values of our independent variables, nor the p values of either of the two control variables, are significant. Accordingly, we prefer either the Fixed Effect or Random Effect regression model for our analysis.

3.5 Econometric Model

For 11 countries ($i = 1, \dots, 11$) and multiple time periods ($t = 1, \dots, 21$), a multiple regression model was developed

$$y_{it} = \alpha + x_{it}\beta + c_i + u_{it} \quad (3.1)$$

where c_i is the country-specific effect, y_{it} is the dependent variable, α is the intercept, x_{it} is the K-dimensional row vector of explanatory variables, β is the K-dimensional column vector of parameters, and u_{it} it is the error overall term. The matrices below summarize the T ($T = 21$) observations for each nation: dependent variable y_i is symbolized as follows:

$$y_i = \begin{bmatrix} y_{i1} \\ \cdot \\ \cdot \\ y_{i5} \\ \cdot \\ \cdot \\ y_{i21} \end{bmatrix}, y_i = [21 \times 1]$$

For independent variable X_i , it is represented by:

$$X_i = \begin{bmatrix} X'_{i1} \\ \cdot \\ \cdot \\ X'_{i5} \\ \cdot \\ \cdot \\ X'_{i21} \end{bmatrix}$$

Given that regression involves four independent variables, $X_i = [21 \times 6]$, The general error term matrix is as follows:

$$u_i = \begin{bmatrix} u_{i1} \\ \cdot \\ \cdot \\ u_{i5} \\ \cdot \\ \cdot \\ u_{i21} \end{bmatrix}, u_i = [21 \times 1]$$

Let's use the letters N and T to indicate the final nation in set i ($N = 11$) and the final year in set t ($T = 21$). Now, we can record NT observations for all nations and eras using the format below.

For dependent variable y , it is represented by:

$$y = \begin{bmatrix} y_1 \\ \cdot \\ \cdot \\ y_i \\ \cdot \\ \cdot \\ y_{11} \end{bmatrix}, y = [NT \times 1]$$

For independent variable X , it is represented by:

$$X = \begin{bmatrix} X_1 \\ \cdot \\ \cdot \\ X_i \\ \cdot \\ \cdot \\ X_{11} \end{bmatrix}, X = [NTXK]$$

For error term U , it is represented by:

$$u = \begin{bmatrix} u_1 \\ \cdot \\ \cdot \\ u_i \\ \cdot \\ \cdot \\ u_{11} \end{bmatrix}, U = [NTX1]$$

Since $E(u_{it})=0$ and $E(c_i)=0$, the data generation process can be described as linear:

$$y_{it} = \alpha + x_{it}' \beta + c_i + u_{it}$$

The model is linear in parameters α and β , individual effect c_i and overall error u_{it}

Independence: $\{X_i, y_i\}_{i=1}^N$ (independent and identically distributed).

The observations are independent between people but perhaps not across time. The random selection of nations ensures this.

Strict exogeneity: $E(u_{it} | X_i, c_i)$

The explanatory variables for all past, present, and future time periods of the same person are assumed to be uncorrelated with the overall error term, or u_{it} . This strong premise, for instance, disqualifies lagged dependent variables. Additionally, it is presupposed that the overall error is unrelated to the effect that is unique to each person. We can distinguish between the fixed effects model and the random effects model using additional presumptions (Schmidheiny, 2013).

3.6 The Random Versus Fixed Effects Model

The individual-specific effect in the random effect model is a random variable that is unrelated to the explanatory variables.

Unrelated effect: $E = (c_i | X_i) = 0$

According to this supposition, the individual-specific effect is a random variable that is not related to the explanatory variables for any of the individual's past, present, or future time periods. Typically, economists do not like such a strong assumption. We can infer from this that the random effect model would not be applied in this study. Later, we used the proper test to demonstrate this.

The individual-specific effect in the fixed effects model is a random variable that is permitted to be correlated with the explanatory variables.

Related effect: $E = (c_i | X_i) \neq 0$

Variance effect: $V = (c_i | X_i) = \sigma^2 < \infty$; $V = (c_i | X_i) = c_{it}^2(X_i) < \infty$

This assumes constant variance of the individual specific effect.

Identifiability rank $(\ddot{X}) = K < NT$ and $E(X_i \ddot{X})$ where typical element $x_{it} \doteq x_{it} - \bar{x}$ and

$$\bar{x} = \frac{1}{T} \sum x_{it}$$

This is based on the assumption that all regressors have non-zero within-variance and that the explanatory variables are not perfectly collinear. As a result, neither a constant nor any other time-invariant variables can be included in X_{it} (Schmidheiny, 2013).

3.7 Results For Fixed Effect Regression Model

Firstly, the independent variables were entered into the model differently. Table 3.10 shows that R&D expenditures are significant and positive. The analysis was continued using model 10 as the final model.

Table 3.10 The Relationship between R&D Expenditures and Economic Growth

Variable / target variable = GDPPC	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
RDEXP	0.71***	0.6***	0.25***	0.57*	0.25**	0.36***	0.13*	0.1*	0.25**	0.27***
INVGDP		1.71***			1.1***	1.88***	1.24**	1.42**	1.51**	1.47***
LABOR			2.73***		2.3***		2.16***	1.9**	1.21**	1.07***
GGCE				0.86*		1.42***	0.82*	1.5**	1.05	3.11***
TECHN								0.1*		0.33**
RES									0.28*	0.11***
No of Observation	231	231	231	231	231	231	231	231	231	231
No of Country	11	11	11	11	11	11	11	11	11	11
Serial Correlation Problem	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cross Sectional Dependence Problem	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note:*** p<0.01, ** p<0.05, * p<0.10

We conduct multiple regression with fixed effects for independent, dependent, and control variables taking into account all of the aforementioned information. Table 3.11 presents the outcomes.

Table 3.11 Multiple regression using fixed effect model.

	Estimate	Std. Error	t value	Pr(> t)
log(RDEXP)	0.27	0.09	2.83	0.005***
log(INVGDP)	1.47	0.208	7.08	2.329e-110 ***
log(GGCE)	1.07	0.315	3.39	0.0008328 ***
log(LABOR)	3.11	0.54	5.86	1.865e-08 ***
log(TECHN)	0.33	0.12	2.73	0.07062 **
log(RES)	0.11	0.09	4.824	3.96e-06 ***
R-Squared	0.51901			
F-statistic:	53.9524	p-value	< 2.22e-16	

Note:*** p<0.01, ** p<0.05, * p<0.10

All predictors have statistically significant p values, as shown in Table 3.11. The inference drawn from Table 3.8 is that ceteris paribus, a 1% increase in R&D spending as a percentage of GDP will have an effect on real GDP growth rates in the observed economies by 0.27 percentage points over the course of the observation period. 51.9% is the coefficient of determination.

3.8 Hausman Test For Endogeneity of The Model

We perform a Hausman test to determine whether to use fixed or random effects, with the null hypothesis being that random effects are preferred over fixed effects.

The main test is whether the regressors and the unique errors (u_i) are correlated; the null hypothesis is that they are not.

We will compare the fixed effects and random effects model results with the hausman test and determine which result to choose. Table 3.9 displays the Hausman test results.

Table 3.12 Results of Hausman Test

chisq = 115.41	df = 6	p-value < 2.2e-16
alternative hypothesis	one model is inconsistent	

The Hausman test tests the null hypothesis that the coefficients calculated with the efficient random effects estimator are the same as those estimated with consistent fixed effects. According to the Hausman test result, fixed effects is a more effective model.

3.9 Results

We know from the test results in Section 3.2 and 3.3 that although the results are statistically significant, we rejected the null hypothesis in the serial correlation, homoskedasticity and cross-sectional dependence tests and will be corrected accordingly. In this section, besides the significance of the variables, we will use some modified functions to test whether we can use them in the final model or not.

We will start with the HAC function that we will use for Serial Correlation and Homoskedasticity. After this step, we will continue with SCC and our model will take its final form.

Table 3.13 Results of HAC

	Coefficient
log(RDEXP)	0.27***
log(TECHN)	0.33
log(RES)	0.11**
log(INVGDP)	1.48***
log(GGCE)	1.07**
log(LABOR)	3.17**

Note:*** p<0.01, ** p<0.05, * p<0.10

We can see that with heteroskedasticity and autocorrelation consistent (HAC) standard errors, the number of technicians is no longer a significant predictor in our model.

Table 3.14 Comparison of Coefficients and Significance

Variable	FE	FE after HAC	SCC
log(RDEXP)	0.27***	0.27***	0.27**
log(TECHN)	0.33**	0.33	0.33
log(RES)	0.11***	0.11**	0.11
log(INVGDP)	1.48***	1.48***	1.48***
log(GGCE)	1.07**	1.07**	1.07**
log(LABOR)	3.17**	3.17**	3.17**

Note:*** p<0.01, ** p<0.05, * p<0.10

We can see that with SCC, the number of researchers is no longer a significant predictor in our model. We see the modified model in the equation 3.2.

$$\text{Log(GDPPC)} = 0.27\text{Log(RDEXP)} + 1.47\text{Log(INVGDP)} + 1.07\text{Log(GGCE)} + 3.11\text{Log(LABOR)} \quad (3.2)$$

Although R&D expenditures' significance declines in the final case, the final coefficients have been reached within the bounds of statistical significance for all four variables using the SSC method.

In the model, it was discovered that the R&D expenditures variable's coefficient was both positive and statistically significant. Panel data tests were run in this main model, and the conclusion was made. This model predicts that an increase of 1% in R&D expenditures as a percentage of GDP will lead to an increase of 0.27 percent in GDP per capita in a select group of countries.

The analysis' findings indicate that the model's labor control variables and domestic investment controls have a favorable impact on economic growth. According to the model, a 1% increase in the share of gross fixed capital investments in GDP causes an increase in economic growth of 1.47% in these countries; a 1% increase in employment causes an increase in economic growth of 3.11%.; increase in the share

of Government Expenditures in GDP causes an increase in economic growth of 1.07% in these countries.



4. CONCLUSION

In contrast to earlier models, the endogenous growth theories that emerged after the second half of 1980 examined the disparities in economic growth between nations internalized technology and identified it as one of the drivers of economic growth. Endogenous growth models predict that the economy will expand and develop more rapidly the more resources it allocates to technological advancement.

Technology advancement, physical and human capital, natural resources, and an increase in population-based labor are some of the factors that contribute to growth. According to studies and models developed to date, R&D activities that are produced using knowledge are among the most significant production resources that influence the welfare level and development of nations. The amount of physical and human capital that nations possess determines the production of new technologies required for new products and methods of production. R&D initiatives by nations, the number of patents, the number of R&D employees, and the number of resources allocated to R&D expenditures as a ratio to GDP can all be used to gauge the country's R&D activities.

Productivity and the competitiveness of the nations will rise as a result of R&D activities brought on by the effective and correct application of technology and high-rate production. It is clear that the R&D sector has evolved into the foundation of the nation's economy as a result of R&D activities. New technologies are created as a result of R&D activities, and these activities take on increasing importance as new products are developed. Investments in knowledge, research, and development will lead to the development of new technologies, which will improve national welfare and permit significant increases in national income levels.

In this study, we analyzed the effect of R&D activities on the economic growth of 11 countries that are considered to be fragile due to their reliance on foreign capital. Specifically, the effect of R&D expenditure as a ratio of GDP on the growth of GDP per capita in Brazil, Chile, Colombia, Indonesia, India, Peru, Russian Federation, Singapore, Thailand, Republic of Korea, and Türkiye for the years 2000–2020 is analyzed in this study.

The Hausman test was used to complete the panel data analysis and determine which of the fixed effect and random effect models was more appropriate. The analysis led to the conclusion that the model, which was produced by including all the variables, is the proper model.

The findings indicate that the share of R&D expenditures in GDP, fixed capital formation, and labor force are all found to be statistically significant and have a positive impact on economic growth. Control variables such as the labor force and fixed capital formation also have a statistically significant and favorable impact on economic growth. The variable with the greatest impact on economic growth is found to be the labor force, followed by gross capital investments, government expenditures, and R&D expenditures, respectively, according to the size of the coefficients. Hence, our results are in line with most of the studies cited in the literature review part that demonstrate that R&D expenditures have a positive and significant impact on economic growth.

Particularly the countries that run current account deficits should increase the value of their exports and should rely less on importing high-value-added products. Because higher R&D expenditures typically enable countries to produce high-technology, so high-value-added products, it is especially important for developing and fragile economies to increase their R&D activities.

Further research can be conducted to analyze the effect of R&D expenditures on the stability of the growth of fragile countries. Specifically, one can infer that as R&D activities enable countries to be able to produce higher value-added products, their reliance on foreign capital would decrease, and in return, they may have more stable as well as higher growth rates. Considering the effects of foreign direct investment, particularly in the R&D sector, it is also important to analyze the effects of the legal system, anti-corruption rules, and protection of intellectual property rights in the growth of economies and the effect on economic stability.

REFERENCES

- 2021, 3 December. (2021, December 3).** *International Women's day 2022: "Gender equality today for a sustainable tomorrow."* UN Women – Headquarters.
<https://www.unwomen.org/en/news-stories/announcement/2021/12/international-womens-day-2022-gender-equality-today-for-a-sustainable-tomorrow>
- Acemoglu D., & Zilibotti F. (1999),** Productivity Differences, Teknik Rapor, National Bureau of Economic Research
- Acemoglu D., & Zilibotti F. (2001),** Productivity Differences, The Quarterly Journal of Economics, 116/2, pp. 563-606
- Acemoglu, D., Johnson, S., & Robinson, J. (2002),** "Reversal of fortune: geography and institutions in the making of the modern world income distribution", The Quarterly Journal of Economics, 117/4: 1231–1294.
- Aghion P.,& Howitt P. (1992),** A Model of Growth Through Creative Destruction. Econometrica, pp. 323
- Aghion P.,& Howitt P. (1998),** Endogenous Growth Theory. Cambridge Mass: MIT Press
- Aghion P.,& Howitt P. (2001),** Competition, Imitation and Growth with Step-by-Step Innovation, Review of Economic Studies, pp. 467-492
- Aghion P.,& Howitt P. (2004),** Growth with Quality-Improving Innovations: An Integrated Framework, Retrieved from https://www.brown.edu/Departments/Economics/Faculty/Peter_Howitt/publication/ahhandbook.pdf

- Alcouffe A., & Kuhn T. (2004), “Schumpeterian Endogenous Growth Theory And Evolutionary Economics”, *Journal of Evolutionary Economics*, 14, pp. 223-236**
- Arrow, K. J. (1962).** “Economic Welfare and the Allocation of Resources for Invention.” In *The Rate and Direction of Inventive Activity: Economic and Social Factors*, pp. 609-626. Princeton University Press.
- Basarac, M., Vuckovic, V., & Skrabic, B. (2013).** Determinants of manufacturing industry exports in European Union member states: A panel data analysis. *Economic Research*, 28(1), 384–397.
- Basu S., & Weil D.N (1998),** Appropriate Technology and Growth. *The Quarterly Journal of Economics*, 113/4, pp. 1025-1054
- Bloomberg.** (2013, June 12). *Greece first developed market cut to emerging at MSCI*. Bloomberg.com. <https://www.bloomberg.com/news/articles/2013-06-11/greece-first-developed-market-cut-to-emerging-as-uae-upgraded>
- Braunerhjelm, P., & Thulin, O. (2008).** Can countries create comparative advantages? R&D expenditure, high-technology exports, and country size in 19 OECD countries 1981–1999. *International Economic Journal*, 22, 95–111.
- Coe, David T., and Elhanan H. (1995).** International R & D Spillovers. *European Economic Review*. 39: 859-887.
- Cincera M. (2005).** “Firms’ Productivity Growth and R&D Spillovers: An Analysis of Alternative Technological Proximity Measures.” *Economics of Innovation and New Technology*. 14 (8): 657-682
- Diao X., Roe T., & Yeldan E. (1999),** Strategic Policies and Growth: An Applied Model of R&D-driven Endogenous Growth, *Journal of Development Economics*, 60, pp. 343-380

Drucker P.F (1984), 'Innovation And Entrepreneurship Practice and Principles', Perfect Bound
Falk, M. (2007). R&D Spending in The High-Tech Sector and Economic Growth.

Research in Economics, 61(3), pp. 140-147.

Frantzen, D. (2000). "R&D, Human Capital and International Technology Spillovers: A CrossCountry Analysis." The Scandinavian Journal of Economics. 102 (1): 57-75

Gallagher, R., Hancock, D., Howes, G., Kendall, J., Thomas, A., & Westcott, T.

(2022, April 19). *Media & Technology Digest - January 2022*. Omdia.

<https://omdia.tech.informa.com/OM022811/Media--Technology-Digest--January-2022>

Goel, R. K., & Ram, R. (1994). Research and Development Expenditures and Economic Growth: A Cross-Country Study. *Economic Development and Cultural Change*, 42(2), pp. 403- 411.

Goel, R., Payne, J., & Ram, R. (2008). R&D Expenditures and U.S. Economic Growth: A Disaggregated Approach. *Journal of Policy Modeling*, 30(2), pp. 237-250.

Griliches, Z. (1973). "Research Expenditures and Growth Accounting." in *Science and Technology in Economic Growth* (B.R. Williams, ed.), pp. 59-83. New York: John Wiley and Sons.

Griliches, Z. (1979), "Issues in Assessing the Contribution of R&D to Productivity Growth." *The Bell Journal of Economics*. 10(1): 92-116

Griliches, Z. (1980a), "Returns to Research and Development Expenditures in the Private Sector." In *New Developments in Productivity Measurement and Analysis* (J.W. Kendrick and B.N. Vaccara, eds.), pp. 419-462. Chicago, Ill.: Chicago University Press.

- Griliches, Z.** (1980b), R&D and the Productivity Slowdown. *American Economic Review*. 70(2): 343-348.
- Griliches, Z.** (1992), The Search for R&D Spillovers. *The Scandinavian Journal of Economics*. 94.
- Griliches, Z.** (1998). R&D and Productivity: The Econometric Evidence. *National Bureau of Economic Research*, 251-268.
- Grossman G M., & Helpman E.** (1989), “Product Development and International Trade”, *The Journal of Political Economy*, 97/6, pp. 1261-1283
- Grossman G M., & Helpman E.** (1990), Comparative Advantage and Long-Run Growth, *The American Economic Review*, 80/4, pp. 796- 815
- Grossman G M., & Helpman E.** (1991), *Innovation and Growth in the Global Economy*, England: Massachusetts Institute of Technology
- Grossman G M., & Helpman E.** (1994), Endogenous Innovation in the Theory of Growth, *The Journal of Economic Perspectives*, 8/1, pp. 23-44
- Guellec D. ve Pottelsberghe B.V.** (2001), “R&D And Productivity Growth: Panel Data Analysis of 16 OECD Countries”, *OECD Economic Studies*, pp. 104-125
- Gürak H.**(2006), *İktisadi Büyüme ve Küresel Ekonomi*, Ekin Yayınları, Bursa
- Human security for all (HS4A). Human Security for All.** (n.d.).
<https://www.ces.tech/topics/human-security-for-all.aspx>
- International Monetary Fund (IMF). 2022. “People’s Republic of China: 2021 Article IV Consultation.” *IMF Country Report 22/21*, Washington, DC.
<https://www.imf.org/en/Publications/CR/Issues/2022/01/26/Peoples-Republic-of-China-2021-Article-IV-Consultation-Press-Release-Staff-Report-and-512248>.

- Jackson, J., & McIver, R.** (2001), *Macroeconomics*, New South Wales:
Irwin/McGraw Hill Australia Pty Limited.
- Jones C.** (1998), *Introduction Economic Growth*, 2, New York:
W.W.Norton&Company Inc
- Jones C.** (1995), R&D Based Models of Economic Growth, *Journal of Political Economy*, 103/ 4, pp. 759-784
- Kellstedt, P., & Whitten, G.** (2013). *The fundamentals of political science research*.
Cambridge University Press.
- Kiselakova, D., Sofrankova, B., Cabinova, V., Onuferova, E., & Soltesova, J.**
(2018), “The impact of R&D expenditure on the development of global competitiveness within the CEE EU countries”, *Journal of Competitiveness*, 10/3: 34–50.
- Korum S.** (1997), "Research, Patenting, and Technological Change", *Econometrica*,
Econometric Society, 65/6, pp. 1389-1420
- Lin J.Y.** (2001), *Development Strategy, Viability and Economic Convergence*,
Economic Development and Cultural Change, pp. 277-308
- Lucas Jr, R. E.** (1988), “On the mechanics of economic development”, *Journal of monetary economics*, 22/1: 3-42.
- Maddison, A.** (2001), *The World Economy: A Millennial Perspective*, Paris:
Development Centre.
- Mansfield, E.** (1965). “Rates of Return from Industrial Research and Development.”
American Economic Review. 55: 310-22.
- Redeker, H.** (2015, August 16). Bloomberg.com.
<https://www.bloomberg.com/news/articles/2015-08-16/morgan-stanley-s-fragile-five-swells-to-troubled-10-in-selloff#xj4y7vzkg>

- Nadiri, M.I.** 1980a. "Sectoral Productivity Slowdown." *American Economic Review*. 70 (2): 349-355.
- Nadiri, M.I.** 1980b. "Contributions and Determinants of Research and Development Expenditures in the U.S. Manufacturing Industries." In *Capital, Efficiency, and Growth* (G. M. von Furstenberg, ed.), pp. 361-392. Cambridge: Ballinger.
- Navigation.** Methodology - Science, technology and innovation - Eurostat. (n.d.).
<https://ec.europa.eu/eurostat/web/science-technology-innovation/methodology>
- Jaegaers et al** (2013): High tech and medium high tech industries main driver of EU 27's industrial growth", in *Statistics in Focus*, 1/2013
- Open knowledge repository.** (n.d.).
<https://openknowledge.worldbank.org/server/api/core/bitstreams/47200e7b-3815-5e28-ab98-634e3696743d/content>
- O'Sullivan, A., & Sheffrin, S. M.** (2003). *Prentice Hall Economics: Principles in action*. Prentice Hall.
- Romer, P. M.** (1986), "Increasing returns and economic growth", *American Economic Review*, 94/5: 1002- 1037.
- Romer, P. M.** (1990), "Endogenous Technological Change", *Journal of Political Economy*, 98/5, pp. 71-102
- Panda, S., & Sharma, R.** (2020). Does technological specialization spur high-technology export? Evidence from panel quantile regressions. *Global Economy Journal*, 20(2), 275–293.
- Park, W. G.** (1995). International R&D Spillovers and OECD Economic Growth. *Economic Inquir*, 33(4), 571-591

- Samimi, A. J., & Alerasoul, S. M.** (2009). R&D and Economic Growth: New Evidence From Some Developing Countries. *Australian Journal of Basic and Applied Sciences*, 3(4), pp. 3464- 3469.
- Sandu, S., & Ciocanel, B.** (2014). Impact of R&D and innovation on high-tech exports. *Procedia Economics and Finance*, 15, 80–90.
- Saygılı Ş.** (2003), Bilgi Ekonomisine Geçiş Sürecinde Türkiye Ekonomisinin Dünyadaki Konumu, Uzmanlık Tezi-DPT
- SE, G.** (n.d.). *Gfk Covid-19 Consumer Pulse Report*. GfK COVID-19 Consumer Pulse Report. <https://insights.gfk.com/gfk-covid-19-consumer-pulse-report>
- Schumpeter J.A** (1939). *Business Cycles; A theroretical, and Statistical Analysis of The Capitalist Process*, McGraw Hill, New York
- Schmidheiny, K.** (2013). *Short Guides to Microeconometrics*. Basel: Unversitat Basel.
- Sepehrdoust, H., Tartar, M., & Davarikish, R.** (2021). Does scientifc productivity stimulate intensified technology exports in developing economies. *Journal of Knowledge Economy*, 12, 2111–2135.
- Seyoum, B. (2004).** The role of factor conditions in high-technology exports: An empirical examination. *Journal of High Technology Management Research*, 15(1), 145–162.
- Simionescu, M., Lazányi, K., Sopková, G., Dobeš, K., & Balcerzak, P. A.** (2017), “Determinants of economic growth in V4 countries and Romania”, *Journal of Competitiveness*, 9/1: 103–116.
- Should we continue to use the term “developing world”? World Bank Blogs.***
(n.d.). <https://blogs.worldbank.org/opendata/should-we-continue-use-term-developing-world>

- Solow R. M.** (1956). "A Contribution to the Theory of Economic Growth." Quarterly Journal of Economics. 70 (1): 65-94.
- Stock, J. H., & Watson, M. W.** (2003). *Introduction to econometrics* (Vol. 104). Addison Wesley Boston.
- Stock, J. H., & Watson, M. W.** (2020). *Introduction to econometrics*. Pearson.
- Sylwester, K.** (2001). R&D and Economic Growth. Knowledge, Technology & Policy, 13(4), s. 71-84.
- Tebaldi, E.** (2011). The determinants of high-technology exports: A panel data analysis. Atlantic Economic Journal, 39(4), 343–353
- United Nations Statistics Division- Standard Country and area codes classifications (M49).** (n.d.).
<https://web.archive.org/web/20100306024500/http://unstats.un.org/unsd/methods/m49/m49regin.htm>
- Wang, E. C.** (2007). R&D Efficiency and Economic Performance: A Cross Country Analysis Using The Stochastic Frontier Approach. Journal of Policy Modelling, 29(2), pp. 345-360.
- Wang, D. H.-M., Yu, T. H.-K., & Liu, H. Q.** (2013). Heterogeneous Effect of High-Tech Industrial R&D Spending on Economic Growth. Journal of Business Research,, 66(10), pp. 1990-1993.
- Wooldridge, J.** (2002). Econometric analysis of cross section and panel data. Massachusetts: MIT Press.
- Yanyun, Z., & Mingquian, Z.** (2004). R&D and Economic Growth Panel Data Analysis in ASEAN+3 Countrie. [Retrieved: 04.08.2022
<http://faculty.washington.edu/karyiu/confer/seoul04/papers/zhao.pdf>]

Zachariadis, M. (2004). R&D-Induced Growth in The OECD? Review of Development Economics, 8(3), p. 331-504.

Zhang, Z., & Gao, Y. (2015, July 15). *Emerging market heterogeneity: Insights from cluster and taxonomy analysis*. IMF.

[https://www.imf.org/en/Publications/WP/Issues/2016/12/31/Emerging-](https://www.imf.org/en/Publications/WP/Issues/2016/12/31/Emerging-Market-Heterogeneity-Insights-from-Cluster-and-Taxonomy-Analysis-43085)

[Market-Heterogeneity-Insights-from-Cluster-and-Taxonomy-Analysis-43085](https://www.imf.org/en/Publications/WP/Issues/2016/12/31/Emerging-Market-Heterogeneity-Insights-from-Cluster-and-Taxonomy-Analysis-43085)





CURRICULUM VITAE

Name Surname : FURKAN KALIN



PHOTO

EDUCATION :

- **B.Sc.** : 2019, Istanbul Technical University, Electrical Engineering
- **B.Sc** : 2019, Istanbul Technical University, MathematicsEngineering