DOKUZ EYLÜL UNIVERSITY

GRADUATE SCHOOL OF SOCIAL SCIENCES

DEPARTMENT OF ECONOMICS

ECONOMICS PROGRAM

DOCTORAL THESIS

Doctor of Philosophy (PhD)

AN EMPIRICAL ANALYSIS OF GREEN TECHNOLOGY DIFFUSION AND CLIMATE CHANGE ADAPTATION ON GREEN GROWTH

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DECLARATION

I hereby declare that this doctoral thesis titled as “An Empirical Analysis of Green Technology Diffusion and Climate Change Adaptation on Green Growth” has been written by myself in accordance with the academic rules and ethical conduct. I also declare that all materials benefited in this thesis consist of the mentioned resources in the reference list. I verify all these with my honour.

Date

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Büşra AĞAN

ABSTRACT

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An Empirical Analysis of Green Technology Diffusion and Climate Change Adaptation on Green Growth

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Green growth is an economic approach that promotes economic development and technological development while also reducing negative environmental impacts, and climatic risks, and improving natural resource management. While theoretical and empirical studies have been done on the link between economic performance, social conditions, technology, the environment, and climate, there is still a gap in the literature evaluates that how these factors interact and affect the process of green growth.

This thesis attempts to fill the gap in the literature by analyzing empirical models developed in the light of the Green Solow model. These models mainly examine the impacts of economic performance, environmental technologies, climatic effects and other key variables of interest in the progress of green growth. In the first section of empirical analysis, we examine the determinants of green technology diffusion with the governmental, social, environmental, and technological indicators. In the second section, we aim to investigate the role of economic performance, the spreading of environmental technologies, climatic effects, globalization, and institutional and environmental variables on the green growth process.

Our findings show that inequality in society has a detrimental effect, while economic performance and other indicators have a significant contribution to the spreading of environmental technologies and products. Moreover, we found that

the economic success, governmental and environmental activities of countries have a substantial impact on the advancement of green growth. The findings also show the negative impact of the interaction between climate change adaptation and carbon emissions on green growth. This finding can be attributed to trade-offs, costs, uncertainties, and policy conflicts. Climate change adaptation measures often divert resources from carbon emissions reduction efforts, limiting the implementation of sustainability. The costs and constraints associated with climatic adaptation measures can hinder investment in green technologies and innovations. Moreover, some adaptation measures may indirectly contribute to increased carbon emissions. Our empirical analyses also show that having higher economic performance, higher investments in environmental technologies and their spreading across countries, and higher adaptation to climatic conditions results in better green growth performance. On the other hand, controlling carbon emission levels is crucial for adopting cleaner and more efficient energy sources, implementing energy-saving measures, promoting sustainable transportation systems, and encouraging eco-friendly production and consumption patterns. Such measures not only contribute to environmental sustainability but also drive innovation, create green jobs, enhance resource efficiency, and improve overall economic performance. Concordantly, it is important to note that the relationship between economic performance and green growth is multifaceted. Green growth represents a comprehensive approach that aims to achieve economic prosperity while simultaneously addressing environmental challenges and promoting sustainability. This emphasizes that economic performance should not be pursued at the expense of environmental degradation, but rather be in harmony with sustainable practices.

Keywords: Green Growth, Economic Performance, Green Technology Diffusion, Climate Change Adaptation.

ÖZET

Doktora Tezi

Yeşil Teknoloji Yayılımı ve İklim Değişimi Adaptasyonunun Yeşil Büyüme Üzerine Ampirik Bir Analizi

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Yeşil büyüme, ekonomik kalkınmayı ve teknolojik gelişmeyi teşvik ederken aynı zamanda olumsuz çevresel etkileri ve iklimsel riskleri azaltan ve doğal kaynak yönetimini iyileştiren ekonomik bir yaklaşımdır. Ekonomik performans, sosyal koşullar, teknoloji, çevre ve iklim arasındaki bağlantı üzerine teorik ve ampirik çalışmalar yapılmış olsa da, literatürde bu faktörlerin nasıl etkileşime girdiği ve yeşil büyüme sürecini nasıl etkilediği konusunda hala bir boşluk bulunmaktadır.

Bu tez, Yeşil Solow modeli ışığında geliştirilen ampirik modelleri analiz ederek literatürdeki boşluğu doldurmaya çalışmaktadır. Bu modeller temel olarak ekonomik performansın, çevresel teknolojilerin, iklimsel etkilerin ve diğer önemli değişkenlerin yeşil büyümenin ilerlemesi üzerindeki etkilerini incelemektedir. Ampirik analizimizin ilk bölümünde, yeşil teknoloji yayılmasının belirleyicilerini, hükümet, sosyal, çevresel ve teknolojik göstergelerle birlikte incelemekteyiz. İkinci bölümde ise, ekonomik performansın, çevre teknolojilerinin yaygınlaşmasının, iklimsel etkilerin, küreselleşmenin, kurumsal ve çevresel değişkenlerin yeşil büyüme sürecindeki rolünü araştırmayı amaçlıyoruz.

Bulgularımız, toplumdaki eşitsizliğin olumsuz bir etkiye sahip olurken, ekonomik performansın ve diğer göstergelerin çevre teknolojilerinin ve ürünlerinin yaygınlaşmasında önemli bir katkısı olduğunu göstermektedir. Ayrıca, bulgularımız, ülkelerin ekonomik başarısının, hükümet ve çevresel

faaliyetlerinin yeşil büyümenin ilerlemesinde önemli bir etkiye sahip olduğu sonucuna varmaktadır. Bulgular aynı zamanda iklim değişikliğine uyum ve karbon emisyonları arasındaki etkileşimin yeşil büyüme üzerindeki olumsuz etkisini de göstermektedir. Bu bulgu ödünleşimlere, maliyetlere, belirsizliklere ve politika çatışmalarına atfedilebilir. İklim değişikliğine uyum önlemleri genellikle kaynakları karbon emisyonlarını azaltma çabalarından uzaklaştırarak sürdürülebilirliğin uygulanmasını sınırlamaktadır. İklimsel uyum önlemleriyle ilişkili maliyetler ve kısıtlamalar, yeşil teknolojilere ve yeniliklere yatırım yapılmasını engelleyebilmektedir. Ayrıca, bazı uyum önlemleri dolaylı olarak artan karbon emisyonlarına katkıda bulunabilir. Ampirik analizler, daha yüksek ekonomik performansa sahip olmanın, çevre teknolojilerine daha fazla yatırım yapmanın ve bunların ülkelere yayılmasının ve iklim koşullarına daha fazla uyum sağlamanın daha iyi yeşil büyüme performansı ile sonuçlandığını da göstermektedir. Öte yandan, daha temiz ve daha verimli enerji kaynaklarının benimsenmesi, enerji tasarrufu önlemlerinin uygulanması, sürdürülebilir ulaşım sistemlerinin teşvik edilmesi ve çevre dostu üretim ve tüketim modellerinin teşvik edilmesi için karbon emisyon seviyelerinin kontrol edilmesi oldukça önem taşımaktadır. Bu tür önlemler yalnızca çevresel sürdürülebilirliğe katkıda bulunmakla kalmaz, aynı zamanda inovasyonu teşvik eder, yeşil işler yaratır, kaynak verimliliğini artırır ve genel ekonomik performansı iyileştirir. Buna paralel olarak, ekonomik performans ile yeşil büyüme arasındaki ilişkinin çok yönlü olduğunu belirtmek önemlidir. Yeşil büyüme, çevresel zorlukları ele alıp sürdürülebilirliği teşvik ederken, aynı zamanda ekonomik refah sağlamayı amaçlayan kapsamlı bir yaklaşımı sunmaktadır. Bu durum, ekonomik performansın çevresel bozulma pahasına değil, sürdürülebilir uygulamalarla uyum içinde sürdürülmesi gerektiğini vurgulamaktadır.

Anahtar Kelimeler: Yeşil Büyüme, Ekonomik Performans, Yeşil Teknoloji Yayılımı, İklim Değişikliğine Uyum.

AN EMPIRICAL ANALYSIS OF GREEN TECHNOLOGY DIFFUSION AND CLIMATE CHANGE ADAPTATION ON GREEN GROWTH

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ABBREVIATIONS

AR	Arellano-Bond Test
CDLM	Lagrange multiplier Cross-sectional Dependence
CIPS	Cross-section augmented Im-Peseran-Shin
CO2	Carbon Dioxide
CSD	Cross-sectional Dependence
DEA	Data Envelopment Analysis
EEA	European Environment Agency
e.g.	exempli gratia (Latin for “for example”)
et al.	et alia (Latin for “and others”)
etc.	et cetera (Latin for “so forth”)
EKC	Environmental Kuznets Curve
EPI	Environmental Performance Index
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
GGGI	Global Green Growth Institute
GMM	The Generalized Method of Moments
GTFP	Green Total Factor Productivity
i.e.	id est (Latin for “that is”)
ICT	Information and Communication Technologies
IPCC	The Intergovernmental Panel on Climate Change
LM	Lagrange Multiplier
OECD	The Organisation for Economic Co-operation and Development
OLS	The Ordinary Least Squares
PPP	Purchasing Power Parity
PRS	Political Risk Services
R&D	Research and Development
SDGs	Sustainable Development Goals
SEDAC	Socioeconomic Data and Applications Center
TAI	Technology Achievement Index
UN	The United Nations

UNCSD	United Nations Conference on Sustainable Development
UNEP	The United Nations Environment Programme
WBCSD	The World Business Council for Sustainable Development
WDI	World Development Indicators
WID	World Inequality Database
WIPO	The World Intellectual Property Organization’

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INTRODUCTION

“Green growth” is a sustainable economic development approach that aims to promote economic growth while also protecting the environment (Zsyman et al., 2012: 144). This approach to sustainable economic development and the environment is based on the idea that economic growth and environmental protection are not mutually exclusive and that it is possible to achieve both at the same time (Adams, 2009: 44). Green growth has become an increasingly important topic on the international agenda in recent years, as more and more people have come to understand the importance of protecting the environment and promoting sustainable development.

The concept of green growth first emerged in the early 21st century, as concerns about climate change and environmental degradation were growing. As a result, many governments and organizations began to focus on finding ways to promote economic growth without harming the environment. This led to the development of various green growth policies and initiatives, such as the implementation of renewable energy sources, the promotion of sustainable practices in agriculture and forestry, and the establishment of conservation areas (Withagen and Smulders, 2012: 22). In the twenty-first century, there has been continued emphasis on green growth, as an increasing number of individuals acknowledge the significance of safeguarding the environment and promoting sustainable progress. Many countries implemented green growth policies and initiatives, and the concept was endorsed by organizations such as the United Nations and the World Bank (Mathai et al., 2018: 63). In the future, it is likely that green growth continues to be a key focus of economic development efforts around the world.

One of the key milestones in the history of green growth was the adoption of the United Nations (UN)’ Sustainable Development Goals (SDGs) in 2015. Member states of the United Nations agreed on these goals, which included several other goals related to the environment and sustainable development (OECD, 2010: 5). In recent years, there are many examples of countries that have successfully pursued green growth strategies and achieved significant economic and environmental benefits. For instance, Costa Rica has achieved nearly 100% renewable electricity generation and has a well-developed system of protected areas, forests, and wildlife reserves.

Denmark has an advanced renewable energy industry and has set lofty goals for cutting down on carbon emissions. South Korea has made considerable achievements in improving energy efficiency and lowering air pollution because to the country's heavy investment in the development of environmental technologies.

In light of these arguments, several studies have investigated green growth's impact on GDP growth and other economic indicators. Maintaining a high quality of living while lowering carbon emissions is crucial to long-term economic success, and several studies have shown a strong association between environmental and economic performance (Aye and Edoja, 2017; Chang and Hao, 2017; Chin et al., 2018; Zmami and Salha, 2020; Khan et al., 2020; Fernandes et al., 2021; Baniya et al., 2021; Hussain et al., 2022). The green growth literature investigates how economic development may be fostered without compromising environmental quality or resource productivity. Green growth is widely regarded as a pathway to attain sustainable development and effectively tackle the challenges posed by climate change. Concordantly, several studies have examined economic, financial, social, institutional, and environmental effects on green growth (You and Huang, 2014; Guo et al., 2015; Feng et al., 2017; Guilló and Magalhaes, 2018; Yuan and Xiang, 2018; Tawiah et al., 2021; Jadoon et al., 2021; Xu et al., 2021; Bo et al., 2022). These studies imply that Carbon dioxide (CO_2) emissions, laws, green technology, environmental and financial performance, weather, resource productivity, social fairness, and institutional policies all have a role in fostering sustainable long-term green growth.

Despite these studies highlighting the significance of green growth as a predictor of economic performance and sustainable development, there is no consensus on how these determinants affect the progress of green growth Furthermore, despite the growing literature on the importance of green growth, there is still lack of theoretical analysis establishing the interactions between the environment and economic growth. This makes it difficult to provide persuasive explanations for the relationship between these factors and to develop effective policies that promote green growth. One of the main challenges in this area pertains to the complexity of assessing the direct consequences of environmental technologies and climatic conditions on environmental-based growth theory. Therefore, several explanatory variables may be of use to estimate long-run relationships.

The theoretical literature on growth has not yet adequately addressed the subject of how possible environmental influences affect green growth. Recently, studies on growth theory have preferred to improve the Solow approach and follow the “Green Solow model”. However, there is a gap in the literature to provide empirical approach for the close relationship between green technology diffusion, climatic effects and its adaptation, and green growth, relying on the Green Solow approach. It also challenges to build generalizable theories or models that can be used in diverse settings due to the intricacy of the interaction between these components. More study is required to determine the relationships between these variables and to pinpoint the most important components in fostering environmentally friendly development. Prior environmental research has mostly examined how CO2 emissions and environmental deterioration impact economic growth on a regional or national scale. However, until now, environmental technologies and the emphasis on climatic conditions have not been evaluated within the growth model. Therefore, in this thesis, unlike other studies, the association between the determinants of the green growth model is comprehensively analyzed in a broad framework with the main determinants.

A strand of the literature has focused on empirical studies that recognize the significance of environmental technologies and the consequences of climatic conditions. The studies on green technology diffusion pay substantial attention to the positive interaction between the spread of technologies and environmental-based growth (Jaffe et al., 2003; Popp et al., 2010; Vona and Patriarca, 2011; Allan et al., 2013; Hall and Helmers, 2013; Wang et al., 2020; Khan et al., 2020; Zecca and Nicolli, 2022). Since a result, spreading green technologies is a crucial aspect of green development, as it helps lessen adverse effects on the environment and boost sustainable progress. Reduce greenhouse gas emissions, safeguard natural ecosystems and biodiversity, and open up new economic opportunities all by spreading and implementing green technology.

Similarly, several studies (Hoa and Limskul, 2013; Eyraud et al,. 2013; Stefanovic et al., 2019; Nyiwul, 2021; Antwi-Agyei et al., 2021; Steensma and Goldsworthy, 2022). have found a positive correlation between climatic technology development and economic development. Further studies (Abidoye and Odusola, 2015; Copiello and Grillenzoni, 2020; Mughal et al., 2022; Espoir et al., 2022) show that severe weather and climate change both have detrimental effects on economic growth.

In the context of empirical studies, a number of main drivers foster green growth. The effects of green growth can vary depending on the specific context and circumstances. It can reduce greenhouse gas emissions, improve air and water quality, promote economic growth and development by creating new jobs and income opportunities, and promote innovation and technological progress. These can reduce poverty, increase economic opportunities, and contribute to overall economic growth and development (Scott et al., 2013: 15-17).

The purpose of this thesis, in keeping with the theoretical framework, is to explore the elements that might impact the spread of environmental sustainability using the environmental-based growth theory. Finding, investigating, and comprehending the elements that foster sustainable, environmentally friendly economic growth is the fundamental objective of this thesis. Furthermore, this thesis contributes by studying these components in separate models to investigate their primary effect on sustainable development and environmental sustainability. A variety of theoretical frameworks and concepts for comprehending and advancing environmentally friendly economic growth are available in the green growth literature. Altering to lower level of carbon emissions, production of environmental-friendly products, resource-efficient processes, and achieving social and environmental justice are central themes of environmental-based improvements.

In theory, the Solow model is an economic model that describes how an economy's growth rate is determined by the interaction between the factors of production (labor and capital), technological progress, and savings rate. The "Green Solow" model incorporates the effects of environmental factors on economic growth (Stefanski, 2013:8). This model can help economists to understand how economic growth and environmental degradation are linked and how policies that promote sustainable development can improve both economic growth and environmental quality (Brock and Taylor, 2010: 131).

Within the scope of this thesis, the Green Solow model is the theoretical approach that our empirical analysis grounds on. The Green Solow model is an extension of the original Solow model that takes into account the effects of environmental factors on economic growth. The Green Solow model developed by Brock and Taylor (2010) is an approach for analyzing environmental factors and their mechanisms as a structural extension of the Solow model. In this model, environmental degradation is treated as a negative externality, which means that it imposes costs on society that are not accounted in the market. These costs can include things like air and water pollution, loss of biodiversity, and climate change. By accounting these costs, the Green Solow model provides a more accurate picture of the costs and benefits of different economic policies and can help policymakers to identify strategies for promoting sustainable development (Adams, 2009: 87).

As the world continues to grapple with the challenges of climate change and environmental degradation, it is important to explore the potential of green growth as a means of promoting sustainable development and reducing negative environmental impacts. More research and analysis are needed to find out the most important factors that affect the success of green growth initiatives and how they can be put into place most effectively.

This thesis makes two types of contributions to the current literature. First, we will dwell on the studies of green technology diffusion. The first section aims to empirically investigate of the determinants affecting the spread of environmental-based innovations on income level, democratic accountability, income equality, socioeconomic conditions, environmental performance, and technological achievements by countries. We will consider theoretical background of the “Green Solow model” derived from the neoclassical framework. The second section will also examine the association between economic, social, political, environmental values, climatic conditions, technology innovations, and globalization effects on green growth. Thus, green growth will be examined within the scope of environmental sustainability, social inclusion, and economic growth.

The thesis at hand is divided into three main chapters that deal with different facets of the issue in order. Chapter One reviews the existence of the concept and history of green growth and its association with environmental technologies, climate change adaptation, sustainable development, and income level across countries. Concordantly, the chapter begins with the definition, purpose, and concept of green growth. Promoting economic growth while lessening environmental deterioration and maximizing resource efficiency is a primary focus. The chapter progresses to elaborate on the connection between green growth, green economy, and environmental-based approaches. Environmental-based growth, the spread of environmental technologies, and dealing with climatic conditions all depend on the strength of this connection. These measures can aid in green and sustainable productivity by mitigating the disastrous consequences of expansion on the natural world. Lastly, the chapter focuses on barriers to the transition to green growth and the effects of green growth policies. There are several barriers, such as economic and governmental, that can prevent or hinder the transition to green growth.

Chapter Two proceeds by introducing the theoretical framework of the studies that comprise environmental-based approach and economic growth. The literature review offered here may be broken down into three parts. The first part focuses on the studies of diffusion of green technology. The studies imply that the environmental technologies, which refers to the widespread adoption and use of clean and renewable technologies, is a important process of green growth. The utilization of environmental products and technologies can assist in mitigating the adverse environmental effects associated with economic growth, including CO2 emissions and pollution.

In keeping with this, several research investigating the connection between climatic conditions and economic development. Greenhouse gas reduction, resource conservation, impact mitigation, and sustainability in the natural world are typical areas of research. The literature on green growth examines the ecological, economic, environmental, technological, institutional, and social aspects of green growth. The utilization of renewable energies and innovative technology to lessen environmental impacts are only two examples of the ways in which these studies consider the potential of “green growth” to foster long-term economic expansion. The research that makes up this body of work focus on the pros and cons of green development from an economic standpoint.

Moreover, the second part of Chapter Two is drawn on the theoretical background of deriving the link between economic performance and the environment with causal determinants. Therefore, this section elucidates the “Green Solow model” and the “technology diffusion model”. These models provide an interaction between economic performance and environmental activities. It depends on the traditional

Solow growth model, which is a framework that economists use to understand how factors like technology, capital, and labor contribute to economic growth. The Green Solow model incorporates additional factors, such as environmental degradation and pollution, and examines how these factors can impact sustainable productivity (Scrieciu et al., 2013: 22). On the other hand, the technology diffusion model is a framework that is used to understand how new technologies are adopted and spread within an economy. Information accessibility, the cost of adoption, and the possible advantages of the technology are only few of the areas the model concentrates on (Jaffe et al., 2003: 11).

The diffusion model can be useful for studying the spreading of environmental technologies, such as renewable energy sources or energy-efficient technologies (Geroski, 2000: 603). By understanding the factors that drive the diffusion of these technologies, policymakers can develop strategies to encourage their adoption and promote green growth. Furthermore, the technology diffusion model is often used in conjunction with the Green Solow model, as the two frameworks complement each other. The technology diffusion model helps us to understand how new green technologies can be adopted and diffused within an economy, while the Green Solow model emphasizes the tensions inherent in balancing economic development with ecological integrity. Together, these models can provide insight into the potential impacts of green growth on the economy and the environment.

Chapter Three shows the findings of empirical analysis built on exploring two questions developed in the thesis. These questions mainly examine the impacts of economic performance and other key variables of interest on the progress of green growth. Moreover, we will estimate two distinct models based on panel data from 1990 to 2020. The results reported in this chapter reveal substantial implications. We will first estimate the potential economic, governmental, social, and environmental determinants of green technologies for a selected sample of countries. The empirical estimates indicate that a negative correlation exists between inequality and the spread of green technologies in the most comprehensive model. Thus, it we can conclude that income inequality can potentially lead to reduced adoption of green technology. This is because new sectors of the economy, especially in energy productivity might emerge thanks to the development and implementation of environmental technology. These industries can provide opportunities for individuals with a wide range of skill sets and education levels, potentially leading to a more equitable distribution of income. Our findings demonstrate positive correlation between other key variables of interest and green technology diffusion.

Secondly, we will consider the main and potential determinants of green growth. Our empirical findings indicate that climate change adaptation, economic growth, FDI, globalization, governmental factors, and technological and environmental protection all contribute to green growth. Our findings reveal that having higher economic performance, carbon emissions, higher environmental technologies, and higher climate change mitigation results in better green growth performance. Ultimately, the success of green growth also depends on the ability of governments, businesses, and individuals to work together to implement sustainable policies and practices.

The plan of the thesis is as follows. Chapter One presents an explanation of the concept and history of green growth and its association with green economy, green growth, and sustainable development. Following this, Chapter Two proceeds to review the comprehensive literature. This chapter also presents the theoretical framework of the studies that comprise green growth and economic growth. Later in Chapter Three, the findings of the empirical analysis based on two models are thoroughly examined. Finally, the conclusion section summarizes the key points and discusses the policy implications resulting from the findings.

CHAPTER ONE
GREEN TECHNOLOGY DIFFUSION, CLIMATE CHANGE ADAPTATION & GREEN GROWTH

1.1. INTRODUCTION

Environmental issues have grown in scope and severity during the past two decades. The notion of green growth links green technology diffusion and the more traditional concerns about sustainable development that support equitable long-run growth and welfare for the world population as a whole. In the 1990s, policies are likely to give more weight to concerns about sustainable development.

The nature and extent of truly global environmental problems are still insufficiently known. There is disagreement, for example, concerning the expected amount and timing of increases in temperature and the probable repercussions of global warming on health and environmental situations. The economic analysis of environmental problems is still sketchy, and existing price signals are unable to take into account most of the environmental familiar in environmental discussions, such as public goods and externalities. The "Polluter Pays Principle" and other economic initiatives have been supported by the OECD as a way to internalize the external costs of pollution (OECD, 2010: 10). With much broader and longer-term concerns, this principle will remain important. However, in the area of international policy discussions, while the use of economic instruments should become more important, the scope for inter-governmental agreements seems at present modest. Therefore, climate change mitigation would make an effort to temper the rise in temperature by employing techniques meant to cut greenhouse gas emissions.

One type of global pollutant called greenhouse gases traps heat that would otherwise radiate into space by absorbing long-wavelength radiation from the atmosphere. It also causes global warming, which has unwelcome effects like as more severe weather events, higher sea levels, and earlier spring thaws. Because emissions of these gases are rising over time and affecting the composition of the atmosphere, there is currently worry about the impact of pollutants on the climate. More and more evidence suggest that people are leading the world's surface heat to increase by burning fossil fuels, destroying tropical forests, and increasing atmospheric concentrations of greenhouse gases (Adams, 2009: 54). Therefore, climate change mitigation involves taking proactive steps to reduce CO2 emissions and slow the rise in temperature levels. The adaptation strategies would also allow the green policies to perform effectively in warmer temperatures. Last but not least, preventative measures assist in lessening the effects of climatic conditions and cutting back on CO2 emissions (Tietenberg, 1997: 32).

Moreover, global climate change is a worldwide concern that may only be solved by international collaboration, particularly to decrease the adverse effects of weather conditions in developing nations. The main environmental issue is the possible consequences of greenhouse gases on global climate changes. It represents a special case of environmental problems because potential environmental damage is very large and irreversible. The implications of global climate change represent a qualitative jump in regard to the other more immediate classical environmental and sustainable development concerns. A growth path is unsustainable if it reduces future well-being as measured by per-capita consumption potential of commercial and environmental goods. Therefore, in terms of per capita consumption, sustainability can be defined as a non-declining consumption potential, broadly defined in terms of efficiency to incorporate the effects of technological advancement. In particular, technology adaptation in this progress requires the industry to devise and adopt better pollution control technologies and, in the best cases, environmentally sound technological processes and products (Hall et al., 2013: 13).

In light of the aforementioned considerations, there are both some positive and many possibly negative implications of global climate change. Regional agricultural effects might be considerable, but research has not yet convincingly shown if global agriculture's overall productivity potential would rise or fall (Antwi-Agyei et al., 2021: 5). Disease patterns could change, and low-lying coastal communities could face substantial risks from the rise in global mean sea level that would accompany global warming.

Environmental disasters and adverse climate effects have in the past decade underscored the degree to which most people suffer when development proceeds without infrastructure and preparation in urbanizing areas. In Europe, as environmental concerns emerged in the 1970s, different countries took on a leadership role on different issues. Germany pioneered the adoption of lead and automobile emissions standards, and the Netherlands instituted an ambitious waste management policy. European Community policy has introduced a complex intervening variable affecting environmental regulation (OECD, 2011: 22).

In the same vein, there are two main challenges that have been moved to the top of the sustainable development and green growth agenda during the 1990s. These are the reduction of poverty and the saving of the environment[1]. First, the poorest developing nations have been severely penalized by debt servicing requirements, deteriorating terms of trade, high capital costs, structural adjustment, and reduced development aid. Concern about their plight has renewed international focus on poverty reduction as a priority for international development assistance. Second, recent scientific evidence of worldwide environmental threats such as climate events and growing recognition of the consequences of rampant natural resource destruction in tropical countries have for the first time integrated environmental protection into the core of development policy goals (Adams, 2009: 89). Indeed, the leaders of the Group of Seven (G7)[2] leading industrial democracies, in what has been dubbed the first Green Summit, agreed at their July 1989 meeting to redouble efforts to assist developing countries to preserve their resources and avoid the deterioration of their ecological systems.

On the other hand, the environmental revolution that swept over Europe and North America in the 1970s and later around the world raised widespread awareness of environmental issues (Adams, 2009: 45). Developing countries often face significant challenges in creating enough jobs to meet the needs of their growing populations. These challenges based on a variety of factors, such as limited access to financing, inadequate infrastructure, and a lack of skilled labor. The creation of urban and rural jobs is particularly important for poverty alleviation and environmental protection efforts in developing countries. If not managed well, urbanization may

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[1] The classification is from the United Nations Department of Economic and Social Affairs (UNDESA). For further information, see: UNDESA. (2013), *World Economic and Social Survey 2013: Sustainable Development Challenges. 2013 (Revision 1),* http://esa.un.org/wpp/documentation/pdf/WPP2012_KEY FINDINGS.pdf

[2] The Group of Seven (G7) is an intergovernmental political forum consisting of Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States.

cause environmental damage and social inequity, despite the fact that development can also provide economic possibilities and higher living conditions. Similarly, the expansion of agriculture and other rural industries can provide employment and income for rural communities, but it can also have disastrous consequences on the environment if not done in a sustainable manner (Baker, 2006: 19). More importantly, the land is the provider of last resort in rural areas and often even in peripheral urban areas. Moreover, poverty has also been on retreat within the borders of most developing countries. The combination of green technologies, fertile alluvial soils, and adequate supplies of water has raised incomes substantially.

Green technologies, such as sustainable agriculture practices, renewable energy, and clean water systems, can have a significant impact on the economic development of rural areas in the developing world. In areas with fertile soils and adequate water supplies, the adoption of green technologies can increase agricultural productivity and incomes and also have positive environmental impacts. However, there are still many rural areas in the developing world that have not yet benefited from the adoption of green technologies. These areas may be located in remote or hard-to-reach locations, or they may lack the necessary capital and infrastructure to support the adoption of these technologies. In addition, some rural areas may have limited agricultural potential due to a variety of factors, such as poor soil quality or a harsh climate.

Many regions around the globe are already in a vulnerable state due to some combination of physical and socio-economic conditions. Climate change effects, should they occur, will serve to exacerbate the vulnerability of these regions and their inhabitants. Taking a precautionary approach to green policy should be required as an anticipatory and not a reactive policy response. Such a response would involve measures to reduce greenhouse gas emissions and achieve climate stabilization at a tolerable and modest level of temperature change.

International agreements might be required in order to implement the precautionary approach. However, since global warming will not produce uniform effects, some countries may gain and others may lose. Getting political agreement on targets and allocating emissions reductions among nations will be far from easy. So-called carbon taxes and emissions permits have been advocated as possible policy instruments for achieving global warming targets. Green technology diffusion is another policy that could become an important tool for meeting environmental goals.

The discussions above, taken together, imply that there is an increased focus on the integration of environmental and economic policies. OECD governments have considered both that environmental issues need to examine in a view of macroeconomic policies and that economic instruments should play more part in environmental regulation (OECD, 2017: 18). Consequently, discussions on the significance of green growth on the world agenda have greatly aided by a deeper comprehension of how technologies spread and how societies adapt to weather events.

In light of these efforts, the remaining of chapter is organized as follows. The evidence for the concept and the history of green growth will be presented in the second section, and we will look at how the spread of green technologies correlates with green development in the third section. Section four of this chapter will introduce the relationship between climate change adaptation and green growth. Lastly, section five summarizes the concluding remarks.

1.2. THE CONCEPT AND HISTORY OF GREEN GROWTH

Environmental dangers associated with climate change and global warming are becoming increasingly apparent nowadays. The social and economic fabric of the entire planet is threatened by these dangers. Undoubtedly, the main attention is paid to global greenhouse gas emissions first. Countries are hesitant in this aspect due to concerns that it harms economic growth and that an international agreement cannot be created.

Gross Domestic Product (GDP) is the most frequently used criterion in determining a nation’s economic growth level. However, events such as the unjust structure of income distribution, the increase in environmental pollution, the deterioration of ecological balance, and the negative effects of global warming have enriched the content, dimensions, and purposes of the concept of economic development in recent years. Thus, this concept has gained a multidimensional structure in addition to economic factors. The opinions that these new factors should be included in the measurement of economic development have brought beyond GDP discussions to the agenda. In this framework, many new concepts concerning environmental and social issues in measuring economic performance have been developed.

In the 19th century, the countries of the world entered a new and distinct stage with the industrial revolution and underwent three related significant developments. The first is the contribution of science to technological development comes to the fore. The second is the discovery of new continents and wealthy classes. The third is the great revolutions in the fields of transportation, thus communication and the resulting flows of people, goods, and capital. This accelerated economic growth by creating great development power. A great depression was experienced during the two world wars and in the 1930s, but the growth accelerated after the Second World War.

Concordantly, the environmental issues that arose due to the Second World War and the subsequent technological developments have become the main agenda of all countries in the world. However, in the 1970s, ecological balance, environmental degradation, and pollution led to the formation of environmentalist approaches and green concepts. Conventional economic growth models have traditionally overlooked environmental considerations, prompting governments and economists to explore alternative economic frameworks. This shift in perspective has also influenced public attitudes towards nature, leading to a growing environmental awareness within society and increased efforts to address environmental challenges. Consequently, sustainable development and the subsequent emergence of green growth have gained prominence globally and have become important topics within economic literature (Hickel and Kallis, 2020: 469).

The history of green growth can be traced back to the early 20th century, when economist Alfred Marshall first proposed the idea that economic growth should be balanced with environmental protection. Smulders et al. (2014) describe sustainable development as “development that fulfills the requirements of the present without compromising the ability of future generations to satisfy their own needs,” which was first proposed in the 1970s in the Brundtland Report. In the decades that followed, the idea of “green growth” arose as a fresh strategy for attaining sustainability that put an emphasis on making more responsible use of the finite natural resources.

As discussed above, environmental issues have existed since the industrial revolution. The only difference from the past is that environmental issues are currently on a global scale. For example, climate change is the visible side of an important ecological crisis that threatens humanity and nature (Wall, 2013: 39). Furthermore, sustainable development has given rise to concepts like green economy, green growth, and sustainable production and consumption in response to ecological catastrophes, global financial crises, economic obstacles, and environmental issues like climate change.

The concept of "green" is widely used and its meaning has been established by consensus much later than its use. It is often thought of as the same thing as sustainable development or as a part of it. Moreover, it is used as a new approach in development, growth, and industrial economics, especially in environmental science, the theory of firm behavior, public policy, income distribution, and other areas of economics. Today, the notion of "green" is front and center as people explore the interconnectedness of the economy, the environment, and the cyclical nature of ecological disasters.

In addition, "green growth" has received much attention as a means to combat environmental decline, resource shortages, and global warming in recent years. As opposed to traditional methods of economic development, "green growth" seeks to minimize disastrous consequences on the environment and maximize the sustainable utilization of materials or substances (Dercon, 2014: 165). Based on developing technology and increasing needs, it is under the influence of interrelated phenomena. It would be important to examine different perspectives on the concept (Bowen, 2012: 8). Particularly, the existence of natural resources and the use of economically suitable reserves increase the importance of green approaches. These approaches need to protect the environment, promote the diffusion of new technological developments, and use natural resources rationally with a sustainable approach (Jacobs, 2012: 10).

Green growth emerges as an alternative approach to the prevailing and existing economic ideology. While contributing to environmental sustainability with green growth, it may also contribute to economic development, income increase, employment, and poverty reduction. Thus, revealing the benefits of investments made in the environment can also ensure that the recession after the economic crisis is eliminated. The origins of the causes of green growth can be searched for in the United Nations conference on the human environment held in Stockholm in 1972, which was a product of the debate on the limits of growth and the environment that began in the 1960s. Following this conference, the UNEP was founded (Adams, 2009: 21).

In reality, the green growth argument gained traction in the wake of the 2008 financial crisis. There are many economic, governmental, and environmental aspects of the 2008 crisis. The effects of the crisis show that the exit from the crisis has been realized with green approaches (Jacobs, 2012: 15). However, the green approaches were not limited to only politicians and green economists; they were also put forward by UNEP as a solution to the crisis. After the global financial crisis, many countries accepted environmental-based approaches as a way to solve current economic situations. It is considered now a part of the concepts of development and sustainability.

All mentioned above reveals that international conferences, signed agreements, and decisions to be implemented should deal with the development of the environmental and green growth within sustainable development. This provides the path for new economic sectors and services to emerge. With the emergence of these, the importance of the green concept is increasing, and as a reflection of all these changes, it may become a part of the plan on various platforms. The environmental awareness and sensitivity of countries worldwide have increased with the emergence of these sectors (Zsyman et al., 2012: 11). Therefore, due to the fact that the environment is an international phenomenon, by its nature, “green” is considered a concept that is the basis of both conflicts and reconciliations.

1.2.1. Green Growth: Definition, Purpose, and Scope

Considering that the increase in world population and consumption brings off many problems that have never been faced before, one of the main issues that many international organizations and countries are currently focusing on is the belief that the development policies pursued so far are not sustainable. Thus, a comprehensive reform is needed. Several issues with sustainability and resource availability have arisen as a result of the rise in the global population and shift in consumer attitudes. Demand for products and services has spurred rapid industrialization, which in turn has put enormous strain on the planet’s ecosystems and its finite natural resources. As the population continues to grow, there is an increasing need for food, water, energy, and raw materials to meet the rising demands. Those resources are limited amount in the world and may decrease or even deplete. On the other hand, issues such as the increasing world population and the destruction caused by consumption in nature, the fact that natural resources will not be enough to meet the consumption in the long run. Among these issues, climate change and its destruction, pollution in the oceans, depletion of natural resources, a decrease in biological diversity, and a dangerous decrease in the amount of clean water on earth can be counted. Faced with all of these threats show the current social and economic systems are not sustainable and that a socio-ecological transformation is inevitable (Baker, 2006: 11).

In fact, “green growth” is a concept that refers to economic growth that is both environmentally sustainable and socially inclusive. The concept of green growth, which is developed in order to get out of the crisis and to maintain a safe life in the future, is structured by many countries and organizations through sustainable development initiatives. In this respect, it can be seen as an aspect of sustainable development. However, it is not just an alternative to sustainable development, it is more like sustainable development and growth with political, economic, social, and ecological complements. Therefore, green growth is a concept that invests in natural capital for ecological sustainability, provides economic development, and gives flexibility to the economy to grow while protecting the environment.

Green growth is an approach to economic development that reduces negative environmental impacts and conserves natural resources. The primary objective of green growth is to improve environmental conditions without significantly slowing economic expansion. Green growth also conducts newly initiated development approaches, that have been considered as potential solutions to global problems. Therefore, it includes several activities that are sustainable urban management, emission control, green employment, technological renewal, climate-friendly technology production, low-carbon economy, clean product design, development of institutional and technical capacity, and economic, environmental, and social sustainability (Popp, 2012: 9).

Paul Ekins (2002) was the first academic to use the term “green growth” and explain it from environmental sustainability and economic growth perspectives. The OECD, UNEP, the World Bank, and other international organizations have produced different definitions of green growth, but they all agree that it is an essential strategy for attaining sustainable development. Thus, the goals of green growth include enhancing energy efficiency, decreasing emissions of greenhouse gases, protect biodiversity, and manage natural resources in a sustainable manner. It also involves measures to promote sustainable transportation, clean technologies, and green infrastructure (Jacobs, 2012: 4).

Green growth refers to a concept that focuses on achieving economic growth while ensuring environmental sustainability and enhancing human well-being and social equity. It entails fostering economic development in a manner that minimizes harmful environmental impacts and promotes the sustainable utilization of natural resources. As defined by the UNEP, a “green economy” seeks to “increase human well-being and social fairness while considerably decreasing environmental hazards and ecological shortages” (UNEP, 2011: 16). In its most basic form, a green economy utilizes few fossil fuels, conserves natural resources, and benefits society as a whole. Public and commercial investments in environmental protection, energy savings, biodiversity preservation, and resource conservation are the cornerstones of a green economy. These investments include public spending, green infrastructure and reforms, and regulatory modifications. In addition, green growth is a socially inclusive concept that promotes low-carbon resource efficiency while reducing ecological scarcity, reducing environmental risks, and improving human well-being and social equity (UNEP, 2011: 14).

Moreover, OECD (2010) defines green growth as a human-centered growth model that prioritizes environmental legislation and the balanced consumption of resources while boosting societal welfare via economic, social, and environmental development (OECD, 2010: 10). According to the World Bank (2012), green growth is economic expansion that benefits all members of society, has a light footprint on the environment, makes effective use of resources, and proceeds without pause in the realization of growth processes.

The European Environment Agency (EEA) defines green growth as helping to raise affluence while preserving the ecological systems that sustain us. "Green growth" seeks to supply human needs for transportation, food, and energy in a sustainable manner. Sustainable development and the concept of a "green economy" have many similarities in their pursuit of a triangular harmony among material, ecological, and social well-being. However, the green economy idea puts more emphasis on economic and environmental factors.

In this regard, the United Nations Conference on Sustainable Development (UNCSD) has highlighted green growth as contributing to the eradication of poverty in addition to sustaining economic growth, expanding social inclusion, and enhancing human welfare. Despite its intimate ties to the idea of sustainability, it comes to the forefront with its emphasis on reducing long-term viable climate change and environmentally friendly growth (Bowen, 2012: 11). In addition to being applicable to all nations, the scope of green growth requires regulations in the policies and approaches adopted according to the specific and concrete conditions of the countries (OECD, 2010: 2).

1.2.2. Relationship Between Green Growth and Sustainable Development

Sustainable development and growth have been discussed since the 1970s within the framework of growth and development theories. The relations between the natural environment and economic activities are explored in "Limits to Growth", a report published by the Club of Rome in 1972. This research claims that within a century we will have hit the limits of global development if the current trend of increasing population, industrialization, food production, air pollution, and the benefit of essential elements continues. The potential result of this predicament is a precipitous and unchecked drop in global population and industrial output (Meadows et al., 1972: 22).

Sustainable development is defined as a concept that analyzes ecological balance and economic growth simultaneously, creates a framework for the effective utilization of natural resources, and places an emphasis on environmental quality

(Hallegatte et al., 2012: 3). In a sense, it underlines the fact that progress is continuous rather than instantaneous.

The current context and growing environmental concerns call for an update to the incorporation of sustainable development techniques into green growth. Green growth is an economic phenomenon that prioritizes environmental sustainability. The push for a green economy, as Reilly (2012) explains it, represents an effort to shift cultural norms in favor of practices that boost the economy, create new jobs, and save the planet. Green growth is gaining importance for the environment and is having a global impact, although its significance is still restricted in comparison to sustainable development. Therefore, most of the countries allocate some of their GDP to green investments and, at this point, provide value to green growth and the economy. In addition, they lay the groundwork for the development of eco-friendly businesses and jobs.

The ideas of green economy and green growth approaches are frequently utilized interchangeably. At this point, the phenomenon of green growth is explained as promoting economic development and growth, while maintaining natural assets that increase the welfare of people and ensure the sustainability of environmental services. In the midst of the financial crisis, the green economy was largely a political concern, with the effects being externalized through the work of various international organizations. In particular, “green stimulus packages” have been accepted to revive green activities in the course of a discussion started by the UNEP in 2008 (Popp, 2011: 4). As a result, several countries used this strategy to deal with the economic crisis.

There are three ways to examine the green economy, such as conceptually, practically, and quantitatively. Strategic planning, policymaking, and the design of comprehensive improvement initiatives all benefit from a theoretical-conceptual lens. The notion of sustainable productivity and several definitions of the environmental-related economy have evolved over the years. The New Green Economic Deal, which can be realized as a moving target through a green economy, green growth, and sustainability, ought to externalize this interdependence between planes and the need of hitting an equilibrium between the demands and interests of different generations. By highlighting the link and interdependence between productivity and the environment, the green economy provides a framework for making sustainability a reality. The phrase “green economy” is often treated as an afterthought in discussions about sustainable development.

In the same vein, the phrase “green economy” refers to agricultural practices that maximize the utilization of biological processes under the influence of solar energy in order to produce goods, services, and energy without having an adverse impact on the environment or climate. It also refers to natural biological processes and the primary production of plants. Therefore, sustainable and balanced development models are inextricably tied to environmental-based growth models and green economy. The applicable performance of the idea of sustainable development for a thorough shift to a green economy, a more productive and socially responsible economy, has emerged. A green economy also refers to a type of model in the economy which maintains all components of economic such as production, consumption, trade, and distribution of economic, political, and social advantages (Adams, 2009: 41). Green growth is the process of increasing the role that environmentally friendly activities and industries can play in boosting the economy. Improving climate resilience by decreasing dependence on fossil fuels and carbon emissions is an essential part of low-carbon development.

There may be some confusion because these two concepts are aimed in slightly different directions. The notion of a green economy attempts to reform the economy by promoting the improvement of social welfare and fairness, while simultaneously lowering environmental dangers and insufficiency by a significant margin. This change may be accomplished primarily through “green” investments, the improvement of green jobs, the progress of a market for eco-friendly products, the promotion of global trade, and the so-called circular economy. The fight against poverty and assistance for developing nations are central to the green economy. Green growth also aims to maintain economic expansion while including natural capital into policymaking and national accounts. Since both green growth and the green economy are presented as solutions to economic and monetary issues, a link must exist between them.

The core concept of the green growth paradigm, into which sustainable development has been included, is that economic growth and progress may be done in a way that is environmentally and social inclusion. By striking a middle ground between economic and environmental concerns, we may work toward a more equitable and sustainable future (Birkmann et al., 2022: 26). Green growth aims to include environmental and social considerations in economic policy and decision-making so that economic development may be pursued in a way that is good for everyone. When compared to sustainable development, the environmental-based model prioritizes economic viability.

1.2.3. Differences Between Green Growth and Economic Growth Theories

There are a variety of different economic theories that have been developed over the years, and they often have different goals and assumptions. Some economic theories aim to increase welfare and provide unlimited economic growth. The idea that the market economy is self-regulating and will naturally tend towards equilibrium is central to classical economics, a term that encompasses a variety of economic theories developed. This is true so long as certain conditions, such as the existence of perfect competition, are met (Baker, 2006: 24). The proponents of this concept believe that economic growth may occur endlessly and should be prioritized as a method of improving people's standard of living. However, it’s important to recognize that there are limits to economic growth. For example, resources such as natural resources and labor are finite. In addition, as economies grow, they tend to become more complex and interdependent, which can create new challenges and vulnerabilities. Therefore, policies and practices that encourage sustainable development must be adopted, as well as the possible social and environmental repercussions of economic expansion.

The detrimental impacts of environmental resources and the environment on the current economy have been largely disregarded. It is a well-established fact that over consumption of the natural resources leads to ecological problems. The current focus of the green growth model is on reducing wasteful production and consumption, curbing wasteful production and consumption, and realizing economic performance without negatively impacting the environment. In light of this, the green growth model provides a solution to the problem of how to promote both economic development and environmental protection without compromising either.

Positive and negative effects on the environment may result from economic expansion (Wells, 2013: 58). It generates opportunities by reducing poverty and enhancing environmental management in both high-income and low-income nations. However, growth carries the potential of severe side effects if markets don't take environmental issues into account and deal with externalities and if the public regulatory system isn't strong enough. As a result, we may define sustainable development as economic expansion that helps reduce income inequality and protects natural resources (Adams, 2009: 108).

The interactions between green growth and economic growth have progressively increased debates on environmental economics and policy. These relations have prompted the question of whether the ongoing increase in economic activity is compatible with ecological balance, the resumed functioning of the ecosystems upon which all human activity depends. Baker (2006) argues that a developing economy's utilization of natural resource inputs and waste disposal modifies the ecosystem upon which it relies. In this context, green growth is meant for manufacturing, which searches for low-carbon emission technology in order to produce and distribute greener and further eco-friendly products.

By contrasting green growth with traditional economic growth, we can see that it is a part of early attempts to create a new development paradigm that takes into account environmental, economic, and social factors all at once. This novel attempt exists in a wide variety of forms. They agree that growth has fundamental, biophysical bounds. This necessitates not only a cutback in the number of resources used in production but also the adoption of new consuming habits that lower overall consumption and alter both the kinds of goods consumed and the demographics of those who engage in this behavior.

Traditional methods of economic performance have relied severely on the depletion of natural resources in ways that are now widely recognized as unsustainable. In virtually every case, many people on both ends of environmental concerns including air and water pollution, ozone depletion, and biodiversity loss. One prominent example of this new environmentalist tactic is the "green growth" paradigm. Economic performance, social progress, and environmental protection must all be taken into account for development to be sustainable. Its purpose is to encourage development that benefits everyone, economically and socially, without compromising the planet's natural stability (Wells, 2013: 88). It focuses not on individual growth but on safeguarding humanity's shared destiny. Green growth appears to be an aspiration that almost everyone believes is desirable (Baker, 2006: 5).

Globally, policymakers have progressively assumed the green growth model to emphasize and encourage their commitment to green economies. The green growth model focuses on economic opportunities rather than the difficulties that come from the pursuit of environmental sustainability. The predominant strategy embraced for curbing environmental degradation is commonly referred to as "green growth". Furthermore, measures such as the United Nations Sustainable Development Goals and the Paris Agreement anticipate ongoing economic development (Alexander, 2015). Green growth encompasses two important ideas: the concept of requirements, especially the vital necessities of the poorest societies of the world to whom precedence might be given; and the notion of technological restrictions on the capacity of the environment to supply existing and next demands (Hickel and Kallis, 2020: 5).

According to the green growth model, which can be considered as a natural resource-oriented growth approach as opposed to the capital-oriented growth approach that forms the basis of the external and internal growth models, the realization of growth is possible by reducing rather than increasing resource consumption. The notion of "green growth" is a dynamic concept. It has nothing to do with a civilization achieving a final stage, constructing static structures, or recognizing fixed characteristics of social, economic, or political activity. Adopting a dynamic understanding of the green growth model enables us to grasp that society will face various futures. The goal of promoting green growth involves envisioning alternative possibilities and embracing a sustainable future through changes in attitudes and values, political transformation, policy innovations, and economic restructuring (Baker, 2006: 7). In addition, promoting the green growth model also involves guiding societal transformation through the interaction of social, economic, and ecological circumstances. The social environment pertains to human norms and values, interpersonal interactions, and institutions, whereas the economic context is concerned with the allocation and distribution of finite resources. Lastly, the ecological context evolves the economic and social contributions and their influence on the environment and its resources.

Consequently, the majority of countries rely heavily on their national environment agency to produce or contribute to national evaluations, and to evaluate progress using environmental indicators connected to the green economy. Similarly, the green growth model is recommended as sustaining the current economic structure. Many studies (Samad and Manzoor, 2015; Du et al., 2019; Tawiah et al., 2021; Nosheen et al., 2021) have been conducted to establish sustainable environments by renaming the idea of profit maximization, which forms the ground of the growth model and also contradicts environmental protection. The overarching goal of such research is to establish a new system in which fundamentally incompatible capitalism economic and environmental activities are brought into harmony. Besides, they contribute to environmental sustainability by examining the determinants of green growth.

1.2.4. Implementation of Green Growth

The unsustainable use of natural resources and neglecting the well-being of future generations can have severe and lasting consequences, posing significant challenges to economic growth and development. It is crucial to align growth strategies with the protection of the natural environment to ensure a sustainable and livable future. Failing to prioritize the preservation of natural resources can lead to irreversible consequences such as water scarcity, pollution of air and water, limited availability of resources, the effects of weather conditions, and the loss of biodiversity. Therefore, it is essential to adopt strategies that promote environmentally friendly growth in order to address these pressing issues.

According to Mazzetti (2012), a number of determinants are required to formulate an effective green growth strategy. The primary goal of any effective green economic plan should be to promote growth and development without compromising environmental quality. It should be ensured that the traditional mentality, in which the environment comes after growth, is moved away. Second, carbon taxes and other market-based incentives, such as pricing the negative externalities of pollution, should be a part of the plan to alter company and consumer behavior. However, it is impossible for fundamental behavioral changes to occur without any changes in all areas. Third, technological innovations that promote greater energy efficiency should be developed through investments in R&D, and job creation in advanced sectors should be encouraged. Convincing green initiatives should avoid supporting short development spurts that will only generate temporary opportunities for unskilled workers. Finally, countries all over the world should set up efficient monitoring systems and independent regulatory agencies to keep an eye on the execution of green laws and make sure that neither commercial nor government interests undermine the efficacy of such regulation. These recommendations summarize an effective green growth policy structure (Mazzetti, 2012: 65). Also, these policies can help create green jobs, which is good for the economy and for long-term growth.

The transformations to a green economy will need both technological innovation and social shifts. The implementation of the green economy is predicated on the identification that nature and all of its natural components are the greatest resources in satisfying human needs; nonetheless, social life is governed by needs (Adams, 2009: 40). Thus, this knowledge can only be attained by a radical shift in perspective and through extensive, sustained effort. To do so, a green economy has many purposes, including making waste harmless, having treatment plants, using environmental architectural practices, having technologies that increase savings, having technologies that remedy the continuity problem, which is the weakness of renewable energy, and having a bicycle and pedestrian transportation systems. It has been considered that activities that do not harm the environment, such as reducing vehicle use by developing transportation systems and technologies that ensure efficient use of the energy produced (Şahin, 2012: 26). As a result of the strategy to be implemented, an economic system that decreases carbon emissions, increases resource and energy efficiency, and provides opportunities for new job opportunities should be obtained.

Environmental issues often have global impacts because the earth's ecosystems are interconnected, and the actions of one country can affect the environment in other countries. Globalization has also made it easier for pollutants and other environmental impacts to be transmitted across international borders. As a result, creating and implementing effective environmental policies requires a global perspective and international cooperation. There are a variety of approaches to environmental policy, ranging from local to international levels (OECD, 2011). At the local level, governments, businesses, and communities can work together to address environmental issues in their own areas. This might involve initiatives such as creating green spaces, promoting sustainable transportation, and reducing waste. Consideration of a domestic green growth strategy to ensure favorable terms, the green growth mainstream mechanism to explore opportunities through existing economic activities, and the green growth policy tools to exploit specific opportunities in spatial and resource systems should all be part of a government's implementation of the green growth strategy. There are three different dimensions to the development and implementation of an environmentally friendly growth strategy (OECD, 2012).

Dimension 1 is called a domestic green growth strategy to ensure conditions. This refers to the steps that governments may take to foster an atmosphere that is conducive to sustainable productivity inside their boundaries. Also, this might involve creating regulatory frameworks that support the improvement of clean technologies, providing incentives for businesses to adopt sustainable practices, and investing in research and development of green technologies. Dimension 2 is made up of green growth mainstream mechanism. This refers to the ways in which green growth can be integrated into existing economic activities. This might involve identifying opportunities for green growth within existing sectors, such as agriculture or transportation, and developing policies to support these opportunities. (Baker, 2006: 20). Dimension 3 consists of green growth policy tools. This refers to the specific measures that governments can take to exploit opportunities for green growth in specific spatial and resource systems. This might involve strategies such as conservation and land use planning, water management, or waste reduction (Baker, 2006: 22).

The formulation and execution of an environmentally friendly growth plan in this context necessitates a holistic strategy that accounts for these three dimensions as well as the unique problems and possibilities that a country or area may face. It is obvious that people should take responsibility in order to control the environmental issues that have become unsustainable and to ensure the future of the world. The fact that the economies are growing day by day is an indication that these problems will not be solved by themselves and will intensify gradually. One of the most efficient strategies to solve environmental problems without compromising human well-being is through green development. However, unlike other theories of economic growth, green growth does not prescribe a specific path to growth (Wells, 2013: 11). Natural assets should be provided at their maximum economic potential on a sustainable basis, and each country should decide and implement an acceptable plan, taking its specific dynamics into consideration.

1.2.5. Contribution of Green Growth to the Economy

A green economy is not only an environmentally important issue but also offers potential economic significance. It has also been explained as an important market opportunity at the point of being a solution to increasing resource prices. As a matter of fact, it is well-known that the green economy market has expanded more rapidly than many traditional markets. Green growth contributes to promoting economic growth and welfare, creating job opportunities for the benefit of all segments of society, expanding aggregate demand and reducing poverty.

As part of the green economic growth process, investments from both the public and private sectors are needed to increase energy efficiency and safeguard biodiversity. Moreover, it is important to increase economic income and provide new business opportunities. In particular, this process provides resource efficiency as an opportunity for green growth. The efficient utilization of resources in the fields of energy, water, and nutrition protection that is required to sustain growth leads to the prevention of resource waste and resource savings (UNESCAP 2012:15). Resource efficiency in part of the green economic growth process is expected to facilitate countries in the process of adapting to international agreements, creating new job opportunities, the emergence of new products and markets, and finding solutions to social and environmental pressures as well as human development.

Overall, green growth can create new sources of growth in efficient consumption of natural resources, in increasing efficiency, in developing innovation for new policies towards value creation and environmental issues, in creating new markets, reassuring investors, and contributing to economic stability (OECD, 2011: 5). Since green growth is low-carbon growth, it not only drives structural changes but also creates new jobs, business lines, and opportunities. Advances in technology, new industries, job opportunities, and skills development, and the effects of change on more traditional sectors, developing new products and markets, reducing environmental pressure by identifying cleaner production sources (OECD, 2010: 2), reduction of CO2 emissions, and enabling the evaluation of effective industrial policies (UNIDO and GGGI, 2015: 5) may create opportunities for resource efficiency and poverty reduction (UNESCAP, 2012: 15).

Similarly, green development benefits from a number of factors. Depending on the circumstances, it can help the environment, the economy, society, and even people's psyches. Ecological benefits, pollution reduction, biodiversity preservation, and natural resource preservation are the foundation of the aforementioned categorization's subcomponents. Then, the savings in energy costs and increased value of your home are economic advantages. Lastly, human health, social advantages, and psychological rewards such as recreation and contentment (Baker, 2006: 10).

One advantage of green growth for the economy is its ability to promote to green jobs and employment (Bowen and Kuralbayeva, 2015: 24). The volatility of oil prices in many countries, concerns about energy supply security, and climate change may cause global environmental crises, and negative outcomes can be eliminated by creating opportunities for green jobs. For this reason, green jobs that have been created in the future with green growth will guide the world and national economies by offering environmental products and services and will also provide environmental investment and employment opportunities. The World Business Council for Sustainable Development (WBCSD) highlights several practical benefits of investing in sustainable business practices related to ecosystems and opportunities (UNEP, 2008: 54). These include the introduction of innovative products and services to generate new revenue channels, reducing reliance on scarce and fragile raw materials by developing substitutes or using abundant and renewable alternatives, and decreasing expenses caused by the scarcity of raw materials. Additionally, investing in sustainable business practices can create new markets for certified and eco-friendly items, develop new enterprises with an environmentally friendly approach, and strengthen the operating licenses of businesses.

Depending on the characteristics of the countries, green growth opportunities may be greater in some sectors than in others. There are variations in the renewable energy sector according to among developing and developed countries because of geographical and climatic conditions. For instance, the construction of green buildings or the disposal of agricultural wastes in the agricultural sector may be observed in developed countries. On the other hand, collaboration and knowledge sharing between countries can facilitate the transfer of expertise and technologies, enabling all nations to seize green growth opportunities and address environmental challenges effectively.

1.2.6. Barriers and Policies to the Transition to Green Growth

Recently, most countries have started to attempt to produce strategies and policies on sustainable productivity and green growth. In the framework of Rio + 20, institutions and organizations such as UN agencies, other international organizations, and development banks tend to expand these initiatives by taking enterprises to share information, provide consultancy services, and provide financial support.

Ecologically sound economic growth, poverty alleviation, and long-term progress are the ends to which "green policies" strive. Included in these policies are a wide variety of initiatives including investing in renewable energy, improving energy efficiency, safeguarding natural resources, decreasing pollution, and supporting sustainable land use practices on a national, regional, and local scale. Just as climate change, pollution, and resource depletion are becoming increasingly pressing issues, so too are environmentally friendly policies. Governments and corporations can do their part to combat these issues and build a more sustainable future by implementing green policies (Adams, 2009: 22).

Similarly, consistent support for green development reforms and strategies is essential in green growth policies. Market-based approaches should be used to establish policy instruments for green growth; the economic, social, and environmental implications of the policy mix selected should be studied; and the gathering and display of environmental and social data should be encouraged (Fankhauser and Jotzo, 2017: 2). Therefore, an environmental monitoring and reporting system and the feasibility of training and social assistance may be established (DCED, 2012: 2).

By and large, several obstacles have slowed the worldwide adoption of green growth models (Toman, 2012: 19). Of these challenges, at first, consideration should be given to monetary and economic constraints. The transition to a green growth model often requires significant upfront investment in new technologies and infrastructure, which can be a challenge for businesses and governments. In addition, green growth may not always align with short-term economic interests, making it difficult to attract financial support. Secondly, technological barriers are also remarkable. The development and deployment of new green technologies often require significant research and development. Both the high initial expenses and the lack of knowledge of the benefits of new technology might hinder their adoption. There are also political barriers. Green growth can require significant policy changes, which can be difficult to implement due to political opposition or lack of support. In addition, green growth may require the coordination of efforts across different sectors and levels of government. Lastly, it is considerably faced with social and cultural barriers. Social and cultural factors, including a lack of understanding about environmental concerns or aversion to change, can also impede the shift to a green development model. Therefore, the shift to green growth demands a comprehensive and coordinated approach that addresses these challenges and supports the development of policies and technologies that promote economic performance in an environmentally responsible manner (Toman, 2012: 22).

Green growth has proceeded through pricing pollution rates, emission performance standards, and carbon trading. Pricing the pollution rate is an important type of sanction to protect the environment according to the OECD. Pricing pollution rates is a green economy policy and proceeds by managing the production process with the least cost and keeping the price instrument broad-based. Government support and production and implementation principles may help to promote green technologies by providing subsidies to minimize fossil fuel consumption. To eliminate the harmful environmental effects, carbon reductions in the use of natural fuels and subjecting them to sanctions are essential (OECD, 2011).

In light of the above explanations, green growth policies are needed to enhance the life quality and deal with international enterprises in the fight against environmental and climatic risks (Baker, 2006: 11). The purpose of green policies is to create sustainable productivity without harming the environment or depleting natural resources by striking a balance ecological goal. Green policies can take many forms, including regulations, incentives, and investments in green technologies and infrastructure (Wells, 2013: 17).

Although green growth process is valid for all countries, it is important for countries to adopt a comprehensive and tailored approach to green growth that takes into account their specific development goals, economic conditions, and environmental challenges, and that promotes sustainable development for all members of society. Many developing countries still prioritize the requirement of services such as poverty alleviation, education, food security, and water and sanitation. In these countries, environmental strategies require to implemented in a way that takes into account these priorities and helps to promote sustainable development in a way that benefits all members of society (OECD, 2010: 2).

In conclusion, it is vital to understand that each country's transition to green growth will be unique in terms of its individual development objectives, economic circumstances, and environmental difficulties. The move to a green growth model might be especially difficult for developing nations due to their limited resources and infrastructure.

1.3. GREEN TECHNOLOGY DIFFUSION AND GREEN GROWTH

The relationship between technology advancement and national wealth has long attracted the attention of scholars and policymakers. Productivity, capital, and labor are the three fundamental factors of economic performance. The output of outcomes and benefits may be increased and their efficiency enhanced with the help of technological advancements. In the 1980s, several people argued that the rapid speed of technological innovation was not having a discernible influence on productivity, which led to a discussion regarding the connection between technical growth and economic success (OECD, 2011). As a result, researchers set their sights on discovering what drives the spread of innovative technologies and how it plays out in terms of GDP expansion. Significant strides have been achieved in our knowledge of the connections between technological progress and improvement of economic activities since then (Geroski, 2000; Hall, 2004). Therefore, technology plays an influential role in fostering economic performance; but, the impact of technology on growth can differ relying on various factors, including the technology itself, the industry in which it is used, and the current economic and regulatory climate.

Technology plays an essential role in fostering on labor markets, and the need for certain types of skills has changed as a result of technological improvements (Rao and Kishore, 2010: 1071). In particular, the enhancing use of digital technologies has led to a shift in the sorts of talents that are in demand, with a greater focus on analytical, technical, and management skills. At the same time, the supply of these types of skills has not always kept pace with the demand, leading to a skills gap in some industries and regions. This can be due to various factors, including an insufficient investment in education and training, an inadequate education system, and other barriers to skill development. To overcome these difficulties, governments and companies must invest in training and education programs that provide employees with the knowledge and abilities to make the most of emerging technology and possibilities (Robertson, 2017: 88). This can aid in the dissemination of technology between nations and narrow the skills gap.

The term “diffusion” refers to the process through which a novel concept or piece of technology is adopted by the general public and integrated into society and the economy. Several factors have significant bearing on the rate of green economic transformation. One key factor is the cost and effectiveness of environmental technologies. Another important factor is the availability of financing. Access to financial resources, such as investment capital and funding for R&D, is crucial for environmental-based activities and innovations (Hall, 2004: 2). In the field of technology studies, researchers often use diffusion models to understand how and why new technologies are adopted and how they spread within a society or economy. These models are useful for identifying the main drivers of technology adoption and spreading the word about upcoming innovations. In a broader sense, it includes all efforts made by a company or organization to utilize the economic benefits of innovation. The diffusion of technology may be organized when firms sell the rights to a patent or license an innovation. Understanding the spread of new technologies is crucial for policymakers, businesses, and researchers, as it can help to inform strategies for promoting the adoption of green technologies and for promoting green growth more generally.

Environmental-based innovation or green technology, often comprehended as clean technology or environmental technology, is technology developed with the intention of lowering its negative effects on the environment (Baker, 2006: 18). Green technologies have many potential applications, some of them include the energy, transportation, agricultural, and industrial sectors. Green technology diffusion refers to the process by which green technologies are adopted and used by different countries, regions, or sectors (Hall et al., 2013: 15). This can occur through a variety of channels, such as international trade, technology transfer, and policy diffusion.

The cost of green technologies is often higher than that of traditional technologies, which can be a barrier to adoption. Green technologies must be able to meet the same performance standards as traditional technologies in order to be competitive. Government policies, such as subsidies and restrictions, can either promote or hinder the spread of environmentally friendly technology. However, public opinion and perspective can also have in the dissemination of environmental technology. Environmental technology promotion is crucial as it facilitates the lessening of adverse environmental effects, the maximizing of resource efficiency, and the facilitating of a more sustainable economic transition.

Environmental conservation and green technology diffusion are global matters that are of paramount importance. When manufacturing firms produce, they may generate negative externalities. Production-related contamination of the environment is the primary issue for businesses (Adams, 2009: 45). In response to the “Industry 4.0” initiative in Germany, “Re-industrialization” in the United States, and “Made in China 2025” in China, governments have embraced as the overarching strategy and end goal for spreading environmentally friendly technologies among their respective manufacturing sectors (Meng et al., 2020: 1). To survive in today's competitive market, factories must use cutting-edge environmentally friendly technology (Baker, 2006: 14). Manufacturing firms need to simultaneously engage in green technology diffusion to meet the limits and necessities of external and internal determinants like environmental legislation. Moreover, there is a mutual influence or connection between environmental rules and the green technology diffusion process. It is possible that the diffusion process may take time in the growth path.

Green growth is environmental-based growth model for long-term development. It paves the way for combating environmental challenges and the overuse of natural resources. Besides this, if economic development surpasses the boundary of accessible natural capital, the depletion of natural resources may result in persistent economic stagnation (Hussain et al., 2022: 1). Furthermore, the green growth model is based on the obvious conclusion that environment is a manufacturing component, but one that has been largely ignored by both classical growth theory and typical economic development patterns (Popp, 2012: 10). The natural environment serves as a type of capital by supplying resources, processing waste, and providing a wide range of green services necessary for human survival, such as maintaining stable climate conditions and thriving ecosystems. As a result, they provide little investment into natural capital while too much into the activities that deplete it. Perhaps more economic growth can occur if these market failures are addressed systematically (Jacobs, 2012: 11).

In view of the foregoing, the purpose of green technology dissemination is to reduce negative environmental impacts and promote the transition to a more sustainable economy (Adams, 2009: 87). There are several specific goals that may be pursued through green technology diffusion (Allan et al., 2013: 7). These goals, at first, begin with reducing greenhouse gas emissions. Green technologies can decrease the level of emissions by displacing fossil fuels with low-carbon alternatives, such as renewable energy sources. Similarly, improving resource efficiency is essential. Green technologies can help improve the efficiency of resource use, leading to lower costs and increased competitiveness. Another objective is to minimize pollution. Green technology can aid in the reduction of pollution and other negative environmental consequences, hence increasing the quality of the natural environment and ecosystems. Later, green technologies can provide new opportunities for investment, innovation, and job creation, particularly in low-carbon and resource-efficient industries. Lastly, green technologies can help reduce poverty and improve social equity by creating new opportunities for disadvantaged groups and by promoting more inclusive activities. More importantly, green technology dissemination aims to bring about a more fair and ecologically friendly global economy that can provide for current and future generations (Reilly, 2012: 21).

Green growth models focus on achieving economic expansion in an ecologically friendly manner while meeting present demands. The purpose of green growth is to boost economic production without adding to environmental problems like carbon emissions and resource depletion. This can be accomplished through the implementation of more efficient innovations, the promotion of low-carbon industries, and the formulation of policies that foster sustainable resource utilization and environmental preservation. The significance of environmentally-friendly technology and the efficacy of various approaches to fostering green growth are still up for discussion. This discourse supports the adoption of green growth models aimed at facilitating the shift to a more equitable and sustainable economy, capable of meeting the requirements of present and future generations (OECD, 2011).

The global agenda often emphasizes the importance of environmental considerations and green technology as fundamental components of green growth, as they contribute to the transition towards more sustainable productivity and an equitable international economy that can satisfy the requirements of the present and future (Geroski, 2000: 7). The pace at which green growth occurs indicates whether the economy is becoming more environmentally friendly through the efficient utilization of resources. Numerous researchers have conducted studies on green growth and its determining factors. Chen et al. (2018: 2) have explored the advancements in green technology that can support green growth. Similarly, Cao and Bai (2018: 4) have highlighted significant connections between the environment and green growth. Lastly, Nosheen et al. (2021: 3) have examined the effect of environmental technology on green growth using the cointegration method. There is strong empirical evidence linking green technology and green growth, and linking production-based technologies and energy use negatively.

As a result, green growth policies should promote greener behavior among businesses and consumers, contribute to businesses and consumers, facilitate the fair and efficient transition of jobs, capital, and innovation towards greener sectors, and provide adequate incentives and assistance for the environmental technologies. These strategies also encourage environmentally responsible practices among businesses and consumers (OECD, 2010). Investment and innovation in environmentally friendly technologies are also prime targets of green growth plans. To this end, green growth plans seek to lessen the distributional effects of change on the least advantaged members of society and mitigate any adverse economic effects on businesses when preserving motivations for higher economic performance.

The adoption and diffusion of green technologies have contribution to addressing climate change by reducing CO2 emissions and mitigating of weather events. For instance, green technologies in the energy sector, such as renewable energy sources, can reduce CO2 emissions by replacing fossil fuels. Green technologies in the transportation sector, such as electric vehicles, can also help reduce emissions by replacing fossil fuel-powered vehicles.

1.4. CLIMATE CHANGE ADAPTATION AND GREEN GROWTH

The impacts of climate change phenomena including rising sea levels, increased weather events, and shifts in temperature and rainfall patterns can be mitigated by the implementation of adaptation methods and strategies. Its primary goal is to preserve communities from climate-related pressures and mitigate hazards connected with climate change. Adaptation requires coordinated actions across many sectors and systems to minimize vulnerability to climate-related risks and build resilience to disruptions. The term “adaptation” refers to the process of modifying and adjusting lifestyle to better resist and mitigate the negative consequences of erratic weather patterns (Allan et al., 2013: 1). In addition, adaptation methods can aid individuals, organizations, and states in being ready for and adjusting to the consequences of climatic conditions. Adaptation to such changes is a kind of development since it increases resistance to pressures associated with climatic effects, which in turn improves social and economic indicators.

The concept of climate change adaptation has a rich history that traces back to the early 20th century, when scientists first acknowledged the potential consequences of increasing atmospheric carbon dioxide levels. Initially, the emphasis was on comprehending the potential effects of rising temperatures and implementing measures to mitigate or alleviate those effects. However, as time has passed, the scope of climate change adaptation has expanded to encompass a broader array of actions. This includes strategies to decrease the susceptibility of communities and systems to climatic effects, as well as endeavors to capitalize on potential opportunities that may arise.

The growing concern over climate risks and the urgency for mitigation garnered significant attention during the 1970s and 1980s, prompting decisive action from the United Nations. In 1988, world leaders convened to form the Intergovernmental Panel on Climate Change (IPCC). Serving as a scientific authority, the IPCC assesses the scientific facts pertaining to weather effects and equips policymakers with crucial information to guide their actions. The growing severity of climate effects and the increasing realization of their widespread repercussions have elevated climate change adaptation to the forefront of international agendas in recent years. Today, climate concern stands as an integral part of international initiatives aimed at addressing the impacts of climatic effects and fostering sustainable productivity (Bowen et al., 2012: 15).

The acknowledgment of climate adaptation is the necessity of mitigating risks and capitalizing on the advantages presented by shifting climatic conditions. It stands as a critical global issue, posing a substantial threat to the welfare on a global scale. Climate change adaptation and green growth are intricately interconnected as they share a common objective of addressing the adverse effects of weather conditions while promoting sustainable development (Adams, 2009: 93). Climate change adaptation contributes to green growth in various ways. One such way is through investments in climate-resilient infrastructure, such as sea walls or flood-resistant roads. These measures help mitigate the economic expenses incorporated with natural disasters and safeguard businesses and communities from the negative consequences of climatic conditions. By making people less vulnerable to the negative consequences of climatic events and boosting their capacity to bounce back from them, adaptation to climate change helps meet sustainability goals and opens up long-term growth potential.

Two major strategies of view emphasize the connection between climate-related conditions and green growth. The first strategy is known as “climate change mitigation,” and it entails adopting measures to lessen or avert the release of greenhouse gases. Increased global temperatures, sea level rise, and altered precipitation patterns are only some of the consequences of CO2 emissions, which trap heat in the atmosphere. Policymakers and decision-makers consider the financial advantages and costs of different responses to the climate change challenge (OECD, 2011). Climate change adaptation is the second strategy, and it shows that efforts to cut carbon emissions need to be paired with regulations and incentives to adjust to new weather patterns. Questions about how much adaptation could cost and how much it could help are becoming more important for both local and international projects. Societies always had to deal with environmental risks and weather conditions, so they have developed numerous economic, social, and technical solutions (OECD, 2013: 24).

On the other hand, there are two paths that adaptation, green growth, and sustainable development might be linked. The first approach involves evaluating the sustainability outcomes resulting from climate change policies. The second approach recognizes that climate change adaptation is influenced by unique socioeconomic and technological development trajectories (Madhuri and Kumar, 2021: 2). Diminishing CO2 emissions and diving the core cause of climatic effects are crucial for boosting the utilization of energy-efficient technology can help with this. This can also contribute to green growth by creating new job opportunities and supporting the development of sustainable industries. Green growth is predicated on the notion that the environment is a crucial kind of natural capital, necessary for both direct consumption and the preservation of production flow (Dercon, 2014: 165). Therefore, environmental deterioration can be viewed as a depletion of capital, which will lower the quality and quantity of recurring services. According to the green growth strategy, all resources could be utilized with consideration for the requirements of future generations (Tietenberg, 1992: 21).

Recently, climate change and green growth have acquired importance on the international agenda. As the factors and benefits of environmental-based approaches and climatic events are more understood, the growing importance will continue to take a place in the agenda in all aspects. The Paris Agreement in 2015, under the United Nations' worldwide development framework, Sustainable Development Goals have been adopted. Similarly, the significance of climate change and its possible disastrous consequences and repercussions have received more attention and admission. This emphasized the significance of global collaboration on climate change (OECD, 2013:

20). On the other hand, climate change poses severe risks to economic development and the fight against poverty. Due to the climatic conditions, developing countries are especially at risk since they lack the resources to adapt to the changing environment (Madhuri and Kumar, 2021: 1). The "greening" of nations is made more difficult by the threat posed by a warming planet. In order to effectively deal with the danger posed by environmental issues and climatic effects, it is essential to engage in both the adaptation and development processes. Both processes, adaptation, and development, involve overlapping and interconnected sets of actions.

Sustainable economic performance notwithstanding weather circumstances and climate change measures plays a critical role in fostering this. There are several ways to help green growth through these initiatives. First, by promoting sustainable development practices and reducing greenhouse gas emissions, green labor efforts like reforestation and conservation projects may efficiently absorb carbon dioxide from the atmosphere. If flood control measures are improved and rural transportation infrastructure is made more robust, resilience can be boosted, economic losses from natural disasters can be decreased, and businesses and communities can be safeguarded from the harmful consequences of climate effects. Therefore, environmental-based plans that incorporate climate change measures can help civilizations flourish economically while also mitigating the consequences of climatic effects (Baker, 2006: 91).

The adaptation process promotes sustainable productivity by decreasing exposure to climate-related consequences and increasing the use of climate-related opportunities. However, there are often two causes of an adaptation gap in a nation. Firstly, the demand effect states that people's interest in climate security and, by extension, adaptation strategies, increases in tandem with their wealth. Secondly, the output effect refers to the spillover externality on the supply side, where inadequate adaptation efforts in one country can have repercussions on neighboring countries or the global community. These factors highlight the importance of addressing adaptation deficits and enhancing climate resilience to foster green growth and achieve sustainable development goals (Fankhauser and McDermott, 2014).

Significant efforts to scale up existing and new green technologies and knowledge are needed to bring about a fundamental transformation of green growth in underdeveloped nations. This is necessary for ensuring a lower level of carbon emissions and adjusting to the consequences of climatic conditions. The transition to environmental-based approaches in poor countries may be supported in several ways through national and international efforts. At first, providing financial and technical assistance may help countries adopt green technologies and practices. Besides, it is important to support the development of policies and regulations of environment. Another way is to invest in research and development to identify and develop new green technologies and approaches.

Environmental approaches and the climate-related process are intertwined in many ways. The dangers and impacts of climatic effects can be reduced by the implementation of environmental-based initiatives. For instance, by encouraging the use of renewable sources, ecological products, and energy-efficient equipment, green development may cut down on the levels of CO_2 emissions.

The transition to a green economy can bring about many positive transformations, including reducing greenhouse gas emissions, promoting sustainable development, protecting natural resources, creating jobs, and reducing pollution. These have involved new approaches whose basic aim is to prevent environmental degradation and ensure the sustainable utilization of natural resources. There is growing attention to green growth because it offers many potential benefits, including the development of new technologies, products, and infrastructure (Adams, 2009: 45). Green growth is based on the idea of using economic growth to support sustainable development, rather than relying on resource-intensive, polluting industries. Investing in green growth can help to drive innovation and create new opportunities for economic growth. These investments are seen as an opportunity to create new jobs and ensure social equality. In addition, green growth help to reduce the risks of resource depletion and environmental degradation, which in turn helps to support long-term economic growth. By investing in green technologies and practices, businesses and governments help to ensure that the resources on which their economies depend are used in a sustainable way. Overall, green growth is attracting increasing attention because it offers the potential for economic growth that is environmentally sustainable and that does not deplete natural resources or contribute to environmental degradation.

1.5. CONCLUDING REMARKS

Green growth’s conceptual foundation and two hotly contested issues are discussed in this chapter. The first part of this chapter is devoted to introducing green growth and its background. In this thesis, we look at how the concept of a “green economy” fit into the current, if tentative, efforts to integrate ecological, monetary, and social issues into sustainable development. Since the 1980s, the term “sustainable development” has been often used in discussions about environmental policy. Adopting a dynamic understanding of green growth also helps us to recognize the economic, social, and ecological crises that the countries faced. The primary objective of green growth is to improve environmental conditions without significantly slowing economic expansion. Therefore, fostering green growth is all about seeing several possible futures and accepting a sustainable one through shifts in perspective and policies as well as political and economic reorganization.

The second half of the chapter shifts its emphasis to the justifications showing the connection between the spread of green technology, adaptation to climatic conditions, and environmental-based approaches to green growth. In the third part, we utilize an empirical approach to investigate the role that spreading of environmental technologies and adaptation to climatic effects play in driving green growth. The effects of the environmental-based growth model on technology diffusion across countries, sustainable development, quality of the environment, climatic conditions, and employment have attracted considerable attention in the literature. There is an increasing focus on the integration of economic performance and green policies. OECD governments have judged that environmental issues will need to influence macro-economic policies and those economic instruments should play a much greater part in environmental regulation (OECD, 2010). Moreover, increasing interest in green growth has indicated which policies can usefully target and promote environmentally friendly technologies, whether processes or products. Technology assessment can be a valuable tool for helping to promote the spreading of environmentally friendly technologies by providing a systematic evaluation of their costs, benefits, and potential risks, and by informing policy decisions (OECD, 2010). There are many different approaches to technology assessment, and the most appropriate approach will depend on the specific context and needs of a given technology or sector. Some common methods used in technology assessment include cost-benefit analysis, risk assessment, and stakeholder engagement (Baker, 2006: 15).

Targeting green technologies and products need not be, at least initially, very constraining or problematic. Thus, investment in almost any energy saving or alternative energy development, for example, seems environmentally friendly in relation to present levels of investment in petroleum and coal technology. Developing a comprehensive green policy mix that includes a combination of regulatory instruments, economic incentives, and other measures can construct a supportive atmosphere for the adoption of green technologies and products. As a result, it may be less of a burden on companies and people to make ecologically responsible decisions.

On the other hand, economic incentives, such as pollution taxes or tradeable emissions permits, can be a valuable adjunct to regulatory policy and are probably most useful in situations where relatively long-term environmental goals are clearly established. Such incentives as taxes on waste disposal and fossil fuel consumption could also be used to ensure that firms maintain financial incentives to conserve energy and resources over the long term.

The policy of green technologies has the potential to grow in significance as a tool for achieving environmental goals. More interdisciplinary and intersectoral methods are needed. Research into methods to boost industrial output and environmental quality has to be consistently funded, and international research partnerships should be encouraged. Governments could also perform a valuable service by evaluating company-run programs in places like waste reduction and energy protection that have the potential to provide economic as well as environmental benefits and publishing information on those economic benefits. International organizations have a significant role as information clearing houses by diffusing information about the impacts of different national policies on the implementation and usage of more sustainable production and innovations.

Because of their geographical and climatic characteristics, their heavy reliance on natural resources, and their limited capacity to adjust to a changing environment, the negative effects of green technologies will be felt most keenly in developing nations (Bernauer, 2013). The poorest people in these nations are highly at risk since they have fewer resources and a lower level of adaptability. A strategy that incorporates both mitigation and adaptation is required. Reducing emissions of greenhouse gases would postpone the onset of climate change and lessen its negative effects (IPCC, 2001c). Even if this strategy is executed, current agreements to struggle with climate change by restricting greenhouse gas emissions will not stabilize atmospheric concentrations of these gases. Adaptive capacity building is a required method to complement climate change-decreasing measures with the goal of reducing the negative impacts of climate change on human life (Bernauer, 2013).

As a result, initiatives to adapt to changing climatic circumstances, increase the diffusion of green technology, and reduce poverty are important priorities. Climate change is already having significant impacts on many parts of the world, and it is likely to continue to do so in the future. As such, it is important to adopt measures that can help communities and ecosystems adapt to these changes. Green technologies and products can play a key role in this effort by helping to reduce greenhouse gas emissions, which contribute to climate change. By increasing the diffusion of these technologies, we can help to reduce the overall environmental impact of our actions and mitigate the negative consequences of climate change.

CHAPTER TWO
LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.1. INTRODUCTION

Environmental policy concerns both the economy and long-term sustainability. During the entire process of switching to a green economy, all potential outcomes of environmental policies and green growth policies must be considered. The environmental-based approach involves promoting economic performance and sustainable development in a way that ensures the continued provision of resources and environmental benefits from natural assets. It recognizes the importance of natural resources and ecosystems in supporting human well-being and aims to ensure their sustainable use and preservation (Popp, 2010: 11). In particular, a term for green economy or low carbon economy, sustainable goods and consumption regarding sustainable development has emerged with recent economic crises and environmental and economic issues.

“Green growth” refers to a type of f environmental approach that is focused on increasing economic performance and development while also reducing negative environmental effects (Baker, 2006: 52). It aims to find ways to create economic growth that is sustainable and does not deplete natural resources or contribute to environmental degradation. The European Union asserts that the development of new products and jobs possibilities in the green economy is intimately tied to boosting human well-being and that green growth is associated with sustainable production, consumption and energy efficiency (OECD, 2017). There are many different approaches to building a green economy, and different countries may adopt different strategies depending on their specific circumstances and priorities. One of these is the widespread acceptance of the idea that a “green economy” is one that functions in ways that minimize negative consequences on the environment, such as through reduced levels of C02 emissions and more effective use of scarce resources (Adams, 2009: 28).

Over the past decade, the issue of technology diffusion has become increasingly prominent in discussions surrounding environmental economics and policy. There are several environmental problems, such as air pollution and climatic effects that might be mitigated if new technologies were developed and widely used.

Factors such as population growth, consumption patterns, and land use decisions also contribute to the overall ecological impact of human activities (Baker, 2006: 34). Moreover, the development of new technologies is influenced by various factors, including economic and governmental considerations. Barriers such as high costs, limited access to financing, and regulatory constraints can impede the adoption of green technologies. While investments in green technology are crucial for reducing environmental concerns, a more holistic strategy that incorporates a variety of elements and methods is required to properly meet these problems. Environmental technologies have gained prominence in recent years due to their increasing importance in mitigating environmental impacts and encouraging the management of efficiency (Rao and Kishore, 2010: 17).

Indeed, the objective of environmental-based approaches is significant for both emerging and developed nations, taking into account their unique environmental and economic contexts. Green growth is an important goal for both emerging and developed nations since it requires addressing current demands while also guaranteeing future generations can do the same (Adams, 2009: 41). Developed economies also have more resources and institutional capacity to invest in green technologies and practices, but they also face challenges in transitioning to a more sustainable economic model. This can involve significant upfront costs and may require changes to established systems and practices.

Secondly, although the bulk of emerging nations produces relatively small percentages level of CO2emissions in comparison to the OECD and established economies, their emissions will rise if they stick to the route of conventional economic development. The production and release of CO_2 emissions and the usage of huge quantities of essential elements all contribute to the worldwide spread of these problems, and developing economies are playing an increasingly important part in this.

As discussed in the first chapter, green growth has an important role in encouraging greener behavior for firms and consumers. Several countries invest in environmentally-friendly technologies and practices to reach sustainable productivity and find solutions to environmental challenges. Funding for R&D, subsidies for the use of clean energy technology, and financial incentives for companies to adopt greener policies are all examples of green investments (Adams, 2009: 25).

Additionally, it can provide new employment possibilities in the area of enterprises, such as renewable energy, conservation and resource management, and sustainable transportation. All these can give both economic and environmental advantages since they can contribute to the potential to lessen the level of CO2 emissions and other types of environmental pollution. They also involve reducing reliance on finite resources, such as fossil fuels, and investing in technologies and practices that are more sustainable and less damaging to the environment.

In previous literature, a green new deal is a policy proposal that aims to address environmental issues and economic inequality by facilitating a shift to a low-carbon, sustainable environment. In recent years, the concept of a “green new deal” to combat climatic effects and foster economic performance and development has gained support. A green new order, environmental-based growth, green economy, green employment, and green collar workers are all terms that have been used to describe this type of endeavor, which some believe began in the 1930s (OECD, 2012: 5). As a result, green growth tackles not one but two pressing issues: the need for developing countries to maintain the economic performance that benefits all residents to combat poverty and enhance the quality of life, and the need for better environmental management to cope with resource depletion and climatic conditions.

Furthermore, green growth is a concept of development that prioritizes the fair and sustainable development of all sectors of society. Decoupling economic growth from the exhaustion of essential elements and environmental degradation are fostered together with resource efficiency and the development of clean technologies. This highlights the significance of shifting to low-carbon and resource-efficient economies, which not only lessen environmental consequences but also open up new possibilities for job development and environmental sustainability (Baker, 2006: 24). By focusing on economic development that is compatible with environmental protection, green growth seeks to create a more sustainable future for all.

Following these arguments, the remainder of this chapter is structured as follows. This chapter reviews the literature review and discusses the theoretical framework of the studies on the green growth approach. The first strand of this chapter is the review of literature that adds to three separate strands of literature. The first strand of literature has dwelled on studies of green technology diffusion. This strand aims to explain the indicators of green technology dissemination by countries in terms of income level, human capital, democratic accountability, income equality, socioeconomic conditions, environmental performance, and technology diffusion.

The second strand of literature focuses on studies related to climate change adaptation. This part evaluates the consequences and effects of climatic conditions and adaptation process on economic performance, particularly with respect to political, socioeconomic, technological, and environmental-based factors. The current literature exhibits the determinants of climatic effects and consequences and climate policies for investments in adaptation technologies.

The last strand in the literature considers studies on green growth and globalization. This strand demonstrates the studies on economic, social, political, financial, environmental, and globalization affecting green growth. Thus, green growth attempts to accomplish environmental sustainability, social inclusion, and economic performance. To achieve this, the growth path sustains environmental quality and social inclusion and develops income growth, economic expansion, and improved well-being.

Moreover, the second part of this chapter is drawn on the theoretical background of deriving economic growth and the environment with causal determinants. Firstly, it presented a technology diffusion model, which is a type of economic model that describes how a new technology or innovation spreads through a population or market over time. It is based on the idea that the spread of technology is influenced by a variety of factors, including the characteristics of the technology itself, the characteristics of the population or market that is adopting it, and the environment (Halls, 2009: 2). This part also shows a fundamental growth model connected with environmental degradation, pollution, and environmental policies through innovations and investments. The model demonstrates how general theory generates trade-offs that are reflective, as well as environmental strain. Economic development that does not compromise environmental sustainability is called “green growth,” and the goal of the empirical version of the environmental-based model is to pinpoint the structural and behavioral components that contribute to this type of growth. Therefore, the model involves analyzing data on factors such as technological progress, capital accumulation, resource use, and environmental regulations to understand how they impact economic performance and environmental outcomes. By understanding these determinants of green growth, policymakers and other stakeholders can design policies and interventions that support both economic development and environmental protection.

The rest of this chapter is classified as follows. Section two reviews the literature on green technology diffusion, climate change adaptation, and green growth. This section reviews empirical and theoretical findings provided by existing literature. Following this, section three introduces the theoretical framework of the thesis. Lastly, section four summarizes the concluding remarks.

2.2. LITERATURE REVIEW

2.2.1. Green Technology Diffusion

The first strand of literature has dwelt on the studies of environmentally friendly technologies. Economic and environmental difficulties, global financial crises, and the societal repercussions of climate change have recently revealed ideas such as green products, green technologies, low-carbon economies, sustainable green production, and consumption (Baker, 2006: 14). In recent decades, technological development and diffusion have become increasingly infiltrated discussions of green economics and policy. There are two main reasons why green technology improves. The first reason is that the speed and movement of technological change have a major consequence on the ecological footprint of human social and financial activities. The second is that green policy interventions impose additional limitations and incentives on the technological development process.

On the other hand, there is a growing emphasis on the spreading of environment approaches and technologies in the global climate change agenda (Adams, 2009: 81). One of the most urgent issues of our day may be mitigated in part by reducing emissions of greenhouse gases. The potential of green technology to reduce CO2 emissions and other detrimental consequences of human activity makes it crucial.

Of all this, recent policies have strongly emphasized the advantages of green technology diffusion and development in mitigating climate change. Particularly important is realizing that specific features of green technology may affect the evolution of environmental policy and the means by which societies adapt to changing climates. For instance, investment in green technology-based innovations is impeded by the uncertainty of climatic conditions in different regions, institutional policies, and by the cost of adapting technologies. Therefore, the primary goal of this first strand of literature is to clarify the connection between the spread of green technologies on key determinants and technology diffusion among developed and developing countries.

Green technology is essential to attaining sustainable productivity by decreasing the negative environmental effects of human activities and conserving natural resources. Environmentally friendly technologies refer to the spread and adoption of these technologies by different sectors and regions around the world. According to Schumpeter (1942: 523), technical progress is defined as invention, innovation, and diffusion. Diffusion refers to the process of spreading and adopting innovation by different sectors and regions. This stage involves the dissemination of new technologies and their integration into society (Schumpeter, 1942: 524). The dissemination of green technology, as Allan et al. (2013: 1) point out, is even more important for climate change than the discovery and discover of these technologies themselves. Green technology is designed to minimize these negative impacts and preserve natural resources. The utilization of renewable essential elements, energy-efficient technology, and eco-friendly manufacturing practices are all viable options (OECD: 2011). According to some studies, the broad adoption of such technology would lead to huge benefits for society (Hall, 2009: 1). Considering potential barriers or drivers is essential that may inhibit the dissemination of new technologies when evaluating their potential impact and adoption. Many researchers have pointed out that evaluations frequently ignore these drivers, which can lead to inaccurate or incomplete assessments of the feasibility and potential of environmental-based technologies. Moreover, Waisman et al. (2019: 1) reveals that governments create policies, strategies, and legal frameworks that will speed up, encourage, and make it easier for people to use new technologies, while also making these efforts stronger.

In fact, there may be macrolevel and microlevel reasons causes for the spreading of environmental technologies. Economic development, government regulations, international commerce, globalization, and public attitudes and knowledge are examples of macrolevel variables that might impact the adoption and proliferation of environmentally friendly technology. Microlevel variables, on the other hand, are more particular, local impacts that might influence the acceptance and spread of environmentally friendly technology such as the attitudes and behaviors of individuals, firms, and organizations (Adams, 2009: 101-103).

In this context, there is a remarkable literature review on the spread of general technology and environmental technology. For example, Allan et al. (2013) investigate the development of environmental technologies in connection to the diffusion of general technology, and they discuss the economic theory that underpins this process. As a result, they suggest taking into account general technology diffusion by countries as a factor in determining how quickly green technologies are adopted. New technologies often take a long time to spread widely, and the rate at which they do so varies greatly.

The majority of previous studies have generally confirmed a connection between economic development and ecological issues. Shafik (1994: 757) investigates how prosperity affects ecological health. According to his findings, several environmental indicators, such as provide to clean water and adequate sanitation, may be improved by boosting income and economic growth. Therefore, economic development and well-designed environmental policy tools are essential to reduce environmental damage and improve environmental quality indicators. Later, Scruggs (1998: 259) investigates how political and economic inequality affects environmental regulations. His findings show that more economic and political inequality can lead to a lower quality of the environment as in the sustainability approach. The greatest method for most countries to obtain a fantastic environment is to become affluent, despite the fact that economic progress typically results in environmental damage during the early phases of the diffusion process (Beckerman, 1992: 481). To evaluate the correlation between environmental deterioration and per capita income, Stern et al. (1996:1151) conceptualize and empirically implement the Environmental Kuznets Curve (EKC) method. Their findings draw the conclusion that more economic expansion can decrease environmental degradation. Regarding the resilience of the ecosystem, Arrow et al. (1996: 13) analyze the correlation between GDP per capita and environmental quality. In general, they find that there is a U-shaped decline in environmental quality as wealth rises, followed by an improvement in environmental quality. In addition, their findings imply that environmental policy cannot be an alternative to encouraging economic growth, such as economic liberalization. Also, Newell (2010: 253) examines the influence of climatic events on technology diffusion. According to the findings, environmental regulations, incentives, and government assistance in R&D investments for technological dissemination are important to the spreading of environmental-based innovations.

A plethora of studies in the literature investigates the association between economic performance, inequality, trade, democracy, human capital, social factors, and green technology diffusion and development at the national level. Hill (1999: 283) analyzes how free trade affects environmental policy in poor and wealthy nations. This study's empirical findings suggest that nations with more liberal trade policies are more likely to rapidly embrace and spread new technologies. The study also attempts to establish a relationship between trade openness regimes in order to empirically validate the presence of the technology impact. Vona and Patriarca (2011: 2201) investigate the linkages between inequality and environmental quality among OECD members from 1985 to 2000. Their findings indicate that the correlation between green technology and inequality is non-linear and strongly dependent on socioeconomic status. In addition, they discover that inequality is inversely related to the spread of green technology in developed nations, but it is dependent on income levels in poor countries. The effect of democratic accountability on governments' choice of green policies has drawn considerable academic interest for decades. You et al. (2015: 189) investigate the effects of financial openness and democracy on CO2 emissions. According to their empirical findings, more democracy does lead to lower CO2 emissions, whereas greater financial transparency does not appear to have any effect on emissions. When it comes to the direct linkages between democracy and technology diffusion, Gao et al. (2017: 1272) examine the link between democracy and technology diffusion. According to their empirical findings, democracy itself has no direct positive impact on technology diffusion, which is measured by patents.

Lv (2017: 900) does a similar analysis for the years 1997-2010, estimating the connection between democracy, income, and level of CO2 emissions. The findings demonstrate that, over a certain economic threshold, democratic accountability reduces emissions. Arbolino et al. (2018: 130) estimate the effects of technology diffusion on green policies employing the Environmental Performance Index in EU countries. They present the environmental-based factors and particularly reveal that economic factors have crucial effects on the process of environmentally-friendly policies. Likewise, Wang et al. (2020: 1) examine the interaction between economic, social, political factors and environmental performance using a panel cointegration test. In contrast to the negative consequences of economic expansion, financial inclusion, and use of energy, their research shows that political freedom, institutional excellence, and ethnic diversity all help to lower CO2 emissions. Khan et al. (2020: 1) confirm a causal interaction between economic performance, trade, green technology, and use of renewable energy, and level of CO2 emissions in G7 nations using common correlated effect and granger causality methods. Furthermore, the function of knowledge and human capital is crucial for green technology diffusion among countries. Regarding the link between human capital investment and environmental quality.

Yao et al. (2020: 1) investigate the influences of human capital on environmental quality for 20 OECD nations from 1870 to 2014. According to their research, human capital and CO2 emissions appear to have a time-varying relationship and a bigger negative correlation. This may suggest that expenditures on higher education in OECD countries have steadily increased since the 1950s. The economy, human capital, and societal and political variables are all significantly impacted by income disparity. On the other hand, the consequences of economic inequality on China's environmental regulation between 1995 and 2017 are examined by Wang et al. (2021: 1). Their findings imply that a widening of the residents' economic disparity encourages more rigid environmental restrictions if there is no official corruption. Currently, Zecca and Nicolli (2021: 1) assess the determinants that influence environmental technologies and eco-friendly development by using a dataset of income inequality, democratization, and patent applications on green technologies from 1980 to 2013. They found that the more widespread use of environmentally friendly technologies was associated with higher GDP and lower income disparity.

The literature is also replete with survey studies on green technological diffusion, development, and ecology. With illuminating the role that technology diffusion plays in the economic analysis of environmental problems, Jaffe et al. (2003: 462) discuss the link between environmental policy tools and the spread of new technologies. Their research also indicates that the effect of ecological rules on the creation and dissemination of new technology may be a crucial factor in deciding the ultimate success or loss of environmental protection over the long run. They also discover that the factors of environmental policy tools, such as investments, taxes, subsidies, and knowledge, have a considerable consequence on the speed and direction of green technology spread. Dean (2003:119) highlights the link between international commerce and policy regarding green technology. While some studies suggest that economic activity has a detrimental impact on environment-based efficiency, others show a favorable association between economic efficiency, income growth, and environmental protection. These are primarily generated by global emissions and global taxes and are also dependent on urban and rural institutions, reform strategies, and aid programs. A supplementary evaluation of the literature by Popp et al. (2010: 1) emphasize the importance of green technology diffusion and development. Their review indicates various impediments to establishing eco-friendly approaches and sustainable environmental development, including resource limits, R&D, and environmental restrictions. Furthermore, they illustrate that this process of diffusion and development builds an interaction between the adaptation of technologies, and information dissemination.

The current studies in the literature have mostly concentrated on empirical estimations across countries. Hamamoto (2006: 299) investigates the influence of environmental rules on the spread of eco-friendly technologies in the Japanese industrial sector. Based on this study’s empirical findings, pollution management spending correlates positively with R&D spending and negatively with the average age of capital goods. Another study by Hall and Helmers (2013: 33) uses the green technology patent types of OECD countries to assess the major characteristics of the patents on green technologies. Their results imply that pledged patents promote the safety and spread of clean and eco-friendly innovations for manufacturing. Jin (2016: 357), on the other hand, investigates international technology diffusion and development using data from the multi-region OECD countries by a general equilibrium model.

A few studies in the literature demonstrate empirically a substantial correlation between growth and green technology diffusion. Of these studies, from 1996 to 2012, Du et al. (2019: 297) analyze how the spread of environmentally friendly technologies affected global carbon output. The level of CO2 emissions per capita have an inverse U-shaped relationship with GDP growth; the effects vary widely from country to country; and urbanization level, industrial structure, free trade, and energy consumption practices have a substantial impact on CO2 emissions. According to their research, a country's economic contribution to lowering global CO2 emissions increases with its per capita income. There are several reasons why corporations may be reluctant to adopt green energy technology. Of these reasons can be, some firms are unaware of the possible benefits of environmental-based technologies, the lack of government incentives or subsidies for green energy technologies. Stucki (2019: 546) uses a firm-level data for Germany, Switzerland, and Austria. The study reveals that just 19 percent of businesses have a favorable connection with investments in green energy technology and receive marginal productivity advantages. These findings may have significant consequences for businesses and politicians when designing green energy regulations and incentives. However, Guo (2019: 96) explores how environmental law affects the diffusion of eco-friendly technologies. The findings of this research are critical for guiding the selection of regulatory systems aimed at fostering innovation via environmental control. When it comes to environmental regulation in China, financial measures such as taxes and fees tend to be more effective. Besides, it's worth noting that even the most stringent local environmental punishment has no effect on green technical innovation.

In particular, Halkos and Skouloudis (2021: 79) estimate the dissemination of environmental technologies between 2005 and 2014. In their study, green technology development and diffusion are evaluated by taking into account factors such as foreign direct investment, the development of human knowledge, institutional performance, and management quality. According to their findings, the EKC hypothesis has been rejected, and inverted N-shape relationship for technological development and N-shape relationship for dissemination have been found to exist. Furthermore, several studies (Aldy et al., 1998: 81; Frondel et al., 2007: 571; Brunnermeier and Cohen, 2003: 278; Goetzke et al., 2012: 189) have also been conducted on the impacts of environmental regulations, environmental products, and global green policies on green technology diffusion. Overall, these studies promote the development and spread of ecologically friendly technology.

Both theoretical and empirical literature consistently highlight the existence of an association with environmental circumstances and the dissemination of environmental technologies. A theoretical model by Policardo (2015: 813) explains the impact of democratization on environmental quality and income level. The results imply that the effect of democracy on environmental quality may vary with a community's level of material affluence. In a country ruled by a rich dictator, environmental conditions may worsen as a result of democratization, but it also has the potential to improve under certain circumstances, as argued by Policardo (2015). Zuhair and Kurian (2016: 129) evaluate the process of environmental impact assessment in the Maldives with respect to socio-economic obstacles using a multi-method qualitative model. Their study provide evidence that the gender gap, political influence, social learning are important components for achieving environmental sustainability. Later, Wenbo and Yan (2018: 713) explore the impact of ecological restrictions on CO2 emissions and technology advancements between 2004 and 2015 in China. According to their research, there is a large U-shaped correlation between CO2 emissions and the severity of ecological restrictions. The relationship becomes more stringent from weak to peak and depends on China's economic growth in fossil fuels.

Theoretically, Mercure et al. (2019: 1019) focus on technological innovation as a determinant of climate change mitigation using energy-environment-economy models. Based on their findings, models' predictions are heavily influenced by how well they reflect monetary and financial aspects and how those elements interact with investment, innovation, and technological progress. In addition, the economic effects of low-carbon efforts are predicted to have the opposite effect in the paradigm of macro innovation theory. On the other hand, Chaudhry et al. (2021: 313) examine how changes in technology and public policy impacted environmental quality from 1995 to 2018. According to their assessment, technological innovation is favorably connected with all environmental indicators; nevertheless, governmental performance has a substantial adverse impact on environmental values. Sun et al. (2021: 1) employ the exponential random graph models to study how diffusion models affect the technology diffusion network of an enterprise. Their findings have a favorable impact on corporate technology diffusion systems, since this leads to the development of dynamic strategies.

The rapid diffusion of environmentally friendly technologies is critical to the creation of a more environmentally friendly world. For green technology to spread, both social and technological progress must happen at the same time. Zeng et al. (2020: 1) explore the effects of technological and attitudinal aspects on environmental technology diffusion. Their results show that increasing consumer pro-environmental views, habits, and attitudes are greatly aided by the diffusion and development of green technology. Likewise, consumer knowledge and concern for green marketing are essential in driving their decision-making process toward green products. Customers' concerns and awareness of green technology diffusion are investigated using the survey method of Hussain et al. (2014: 9). The survey data consists of 300 responses from Pakistan. The results of their study showed that customer awareness is strongly linked to the process of buying green products. This finding is important for Pakistan's environmental sustainability, and may be further supported through effective policies. Lastly, the effect of democracy and societal capital on ecology is later dissected by Obydenkova and Salahodjaev (2017: 182). They conclude that free and fair governments are more likely to prioritize ecological concerns when they have high levels of cognitive capital. The acceptance of environmental measures is considerably bolstered by a rise in the general population's level of cognitive capital under a democratic government.

In the same vein, substantial attention has been dedicated to the part of consumers' cognitive activities in the adoption and diffusion of green technologies. Thus, consumer habits, attitudes, and awareness processes have been empirically demonstrated in other studies (Torras and Boyce, 1998: 147; Mansor et al., 2014: 27; Knobloch and Mercure, 2016: 39; Suki et al., 2016: 262) and those are found to be crucial for the implementation of green technology diffusion.

Green technology diffusion and green policies have been studied by a number of researchers, with a focus on understanding how these technologies are disseminated and adopted. Many of these studies have used survey research methods to gather data and insights on these topics. The primary purpose of these studies is to better understand the elements that drive the widespread adoption of green technology and laws so that we may better design strategies to facilitate this process. Policies that support the implementation of ecologically-friendly innovation are referred to as green policies. These policies can take many forms, including subsidies and incentives for the adoption of green technologies, regulations to encourage their use, and funding for research and development in this area. Therefore, green policies aim to promote the spread of these technologies to safeguard the environment and lessen the planet's negative consequences caused by human activities. The effectiveness of green policies based on several factors, including the strength of environmental laws and regulations, the availability of incentives and subsidies, efforts to reduce negative externalities, investment in knowledge, and the socio-economic and political conditions of society. Due to rising concern about climatic effects and consequences, environmental-based approaches have received considerable attention in recent years. As a result, more funding is going toward studies of this topic, and efforts are being made to increase the use of environmentally-friendly technologies.

Climatic events are a major concern all over the world, as they can have significant impacts on human health and the environment. It is also driven by a variety of human and natural factors and is a contributing element to global warming. In response to these challenges, green technology has been widely adopted as a way to address imbalances in energy supply and protect the climate. The objective is to learn more about what factors affect the spread of environmental technology so that we can do more to encourage their widespread usage. This includes a thorough examination of the determinants that may affect the diffusion of these technologies. Given its importance, it is notable that a successful transformation of economies around the world to more sustainable patterns of production and consumption will need widespread adoption and diffusion of green technologies.

2.2.2. Climate Change Adaptation

The second strand of literature explored in this study centers around research on climate change adaptation. Adaptation entails the actions taken by individuals, communities, and governments to anticipate and address the consequences of climate change. These actions can encompass both immediate and long-term strategies and may yield both positive and negative consequences for economic growth. The literature in this field seeks to comprehend the diverse array of factors that can impact the efficacy of climate change adaptation endeavors, encompassing political, socio-economic, technological, and environmental aspects.

The current literature considers determinants of climate concern and climate policies for investments in adaptation technologies. The importance of technological diffusion mechanisms in realizing the goals of climate policy has been stressed ever since the Kyoto Protocol was ratified. The Intergovernmental Panel on Climate Change (IPCC) has repeatedly stressed the importance of the scientific community’s evaluation of climate policy and sustainable development (IPCC, 20114). There have been numerous studies that have explored the importance and determinants of technology creation for environmentally friendly technologies. These technologies, known as green innovations, can have a range of features that can influence their adoption and effectiveness in addressing climate change. Factors such as the cost, efficiency, and ease of use of these technologies can all impact their uptake and the development of related processes.

Solow (1956: 65) argued that innovation has an essential role in driving economic growth over the long term. In his model, he proposed that technological progress was a primary driver of economic growth, and that this progress was driven by the development and adoption of innovations. Solow asserts a causal relationship between innovation and economic growth with the former causing the latter. The role of innovation in promoting economic performance has been widely recognized by economists and policymakers from the introduction of this notion. Subsequently, Taylor et al. (2005: 348) have concentrated their attention on environmental innovations, technological changes, laws, and policies. There are considerable studies of literature on the mitigation of climate effects. Numerous of these studies are of a regional nature, studying the consequences of climatic conditions on specific areas or nations. Other studies focus on understanding the phenomenon of weather conditions itself, predicting the relationships between its determinants, and exploring the association between climatic effects and economic performance.

A strand of the literature has concentrated on the climate effects and consequences using cross-country panel data. According to Horbach (2008: 163), a study that used two different German panel databases to explore the consequences of environmental innovations and their underlying factors, technological capability development (e.g., knowledge-based capital) contributes significantly to environmental improvements. This study's results imply that investments in technological capacities may be crucial for fostering the creation and widespread use of eco-friendly technology. The factors that influence green investment are the primary emphasis of Eyraud et al. (2013: 852). Their empirical finding demonstrates that green investment contributes significantly to economic expansion, low interest rates, and high fuel costs. Therefore, they draw the conclusion that green energy is promoted by environmental legislation. Likewise, Zerihun et al. (2014: 382) examine the determinants of agricultural technology adaptation. Their results show the effect of innovation in poverty and climate change mitigation. Another study conducted by Trærup and Stephan (2015: 435) evaluates the climate change adaptation technologies in Lebanon using regional data from the technology needs assessment project. Their results of this study showed that low-cost technologies were more likely to be deployed in the agriculture and water sectors, as they required less effort to implement. Overall, the findings suggest that the adoption of climate technologies affected by factors such as cost, feasibility, and sector-specific needs.

Mandel et al. (2020: 609) employ a parametric epidemic diffusion model to investigate the effects of technological diffusion on climatic effect technologies in the areas of renewable energy, agriculture, and electro-mobility. Their findings conclude that technological spreading was more effective in the agriculture and electro-mobility sectors than in renewable energy. This suggests that the adoption of climatic effects and environmental technologies may be influenced by sector-specific factors, as well as the characteristics of the technology itself. Recently, Steensma and Goldsworthy (2022: 569) have investigated a study that examined the environmental performance effects of climate change adaptation technologies. Their research design is based on three types of environmental performance: environmental impact, ecological impact, and sustainable production. Their results of this study show that environmental performance can help to fill a knowledge gap between the trade-offs and co-benefits of these technologies for the environment.

Ndamani and Watanabe (2016: 201) investigate the consequences of socio-economic determinants on the climatic adaptations of farmers in Ghana using a logistic regression model. Their empirical findings imply that annual income, household size, education level, credit, and information access are significant factors in the adaptation process. From 1990 to 2015, Alvi et al. (2020: 1) use geographical and socioeconomic parameters to explore the effects of adaptation to climatic conditions. Their empirical results indicate that the farmers of African countries could not manage to adjust to climatic risks. In a recent study on climate change adaptation, Qazlbash et al. (2021: 1) examine the determinants of climatic effects in Pakistan, including socioeconomic factors, gender, age, family size, and education. The researchers shared their findings to raise public understanding of climate change's effects on society and the natural world. This study highlights how crucial it is to examine a wide variety of factors that might affect the success of climatic strategies. Baiardi and Morana (2021: 1) use a special Eurobarometer survey to explore the interactions between climate change concerns and various socio-demographic, political, and economic factors in Europe. There is a directional association between climate concerns and factors such as income, secondary education, perceived physical impact, and social trust.

The literature is also replete with studies of regional climate change adaptation research. Hoa and Limskul (2013: 651) analyze the interactions between level of CO2 emissions, trade, economic performance, and crises in Thailand for 1990–2008 period. The results show that CO2 emissions had a significant and efficient causal relationship with trade, investment, and financial services. These findings suggest that CO2 emissions may have important impacts on economic activity and trade, and that efforts to reduce emissions may have broader economic benefits as well. Furthermore, Stefanovic et al. (2019: 319) investigate the association between climate change adaptation and demographic factors, income, and risk perception in the farming sector in Kenya. Their findings indicate a valuable positive influence on the workforce, age, extension services, farmers' groups, and cooperatives, whereas there is no significant association with gender, human capital, and income/ wealth.

Likewise, the above findings have been confirmed in several recent investigations in the literature that provide similar evidence. For instance, Yeganeh et al. (2020: 1) investigate the climatic policies and parts of regional ecosystems in US cities, and they find that these policies have a favorable impact on federal efforts to adapt to climate change. Likewise, Ojo et al. (2021: 792) analyze the effects of climatic technologies on agricultural output in four regions of South Africa using a multivariate probit model. Their empirical findings indicate that demographic factors and some determining factors such as place, experience, income, training, and permission for credit influence climate change adaptation technologies.

Nyiwul (2021: 298) examines the technological improvements in water-related climate change adaptation. The study indicates that the countries most affected by water stress are the least innovative ones. Thus, the findings suggest that African countries suffering from water stress may need to better design water-related adaptations to climate change. Lastly, Antwi-Agyei et al. (2021: 12) collected data from 150 farmers in Ghana to examine the awareness of climatic effects and its consequences on farmers. Their empirical evidence demonstrates a substantial correlation between climate change awareness, adaptability, and demographic characteristics. On the other hand, the climate adaptation process in different regions has shown comparative reactions to climate variability, particularly in gender differences. For instance, Nabikolo et al. (2012: 203) analyze climate change adaptation decisions for females and males by employing cross-sectional data from 136 households in Uganda. Their findings show that the climate change adaptation decisions of females are more dependent on and sensitive to variables than those of males. They conclude that gender is the only demographic factor significantly associated with the choice of climatic conditions. Overall, these findings suggest that gender may be an important factor in understanding and predicting adaptation decisions.

Furthermore, Koubi et al. (2012:113) explore the association between climate conditions such as temperature and rainfall, armed conflict, and economic performance. In the first step, they calculate how the weather will influence GDP. According to their research, climate change has little born on economic expansion. The second step involves the utilization of indicators of an interaction term between a governmental structure and economic development. Their findings suggest that civil strife is more likely to break out in non-democratic nations when economic conditions worsen. The consequences of climate-related disasters on economic performance from 1980 to 2007 are estimated by Bergholt and Lujala (2012:147). Their two main findings contradict past research by suggesting that climate-related calamities reduce economic expansion. However, the likelihood of war is not affected by climate-related calamities. This suggests that rising incomes may not be one of the main causes of civil war. Given that the transmission of environmental-related technologies has risen in recent years, Ferreira et al. (2020: 1) investigate the effect of knowledge transfer and reduction of climatic conditions on economic performance using multiple regression models for a panel dataset. They obtain evidence that technology transfer and climate change can promote economic performance. Many studies have identified climate change poses a serious risk to future economic expansion. Of these, a current study by Kahn et al. (2021: 104) explores the climatic consequences on economic performance by employing a stochastic growth model with a panel dataset consisting of 174 countries between 1960 and 2014. Their results show that economic growth has negative contribution to changes in temperature.

Environmental policies that are related to CO2 emissions are also taken into account by studies. For instance, Van Der Zwaan et al. (2002: 1) analyze the influence of environmental-based technologies on reduction of CO2 emissions and carbon tax levels. They find that the development of non-fossil energy technologies is an important option to cut down on emissions. Zhou et al. (2020: 1) investigate how Chinese environmental and energy policy affects technology development. They find that the command-and-control regulations and market-related regulations have positive impacts on environmental technology progress. In addition to the studies mentioned above, Simonet and Leseur (2019: 621) evaluate the effects of human factors at the decision-making process on climate change adaptation. Their study implies that the fundamental barriers are in the resource, governance, and awareness levels of climate issues, while the possible drivers are mainly organizational level. Therefore, they suggest that understanding the challenges and drivers of climate change policies has a crucial aspect. A small number of studies (Cosmas et al., 2019;

Espoir et al., 2022) that establish a linkage between the level of CO_2 emissions and economic performance.

The empirical studies on climate change adaptation in the literature have mostly concentrated on the measurement of multivariate analysis. An extensive study is provided by Dell et al. (2008:1). They investigate the impacts of climatic conditions on economic performance. Their study provides evidence that, in developing countries, increased temperatures can negatively affect agricultural productivity. These results show how complicated the climate-economics connection is and how many different factors need to be taken into account to get a comprehensive approach. Likewise, Jones and Olken (2010: 1) employ fixed effects regression to estimate the link between international trade and climate shocks in developing countries from 1900 to 2006. Their results demonstrate that high temperatures in poor countries result in negative and significant effects on the growth of their exports.

Another contribution to the empirical studies of climatic effects is by Nasir et al. (2019: 131) make a further empirical addition to climate change research by examining the link between ecological factors and economic performance, FDI, and financial improvement. Their research shows a favorable correlation between FDI, economic performance, and environmental degradation. Copiello and Grillenzoni (2020: 49) examine the cause-and-effect relationships between human activities and climatic factors. Their empirical results lend weight to the idea that humans are responsible for both causing and responding to climate change. The finding also has beneficial feedback effects on demographic and economic performance. Likewise, Mughal et al. (2022: 1) investigate the causal links between environmental pollution, energy use, technological innovation, and economic development. Their findings demonstrate a reciprocal link between energy use and economic expansion.

Overall, there are some theoretical studies (Rezai et al., 2013; Acemoglu et al., 2014; Taylor et al., 2016; Tol, 2018; Stock, 2020; Fu et al., 2021) that also explore the effects of climatic conditions and innovations by focusing on macroeconomic issues, for example, address agricultural innovations that are important to mitigate the harmful consequences of climatic conditions in developing nations. Later, Millner and Dietz (2015: 380) debate the theoretical channels of climate change adaptation and economic development using neoclassical growth. Theoretically, this means that, in order to decrease the consequences of global warming, investments may be made in either productive capital that is resistant to climate change or adaptive capital, which is not necessarily productive but mitigates climatic harm. They also conclude that structural changes in economic development resulting from adaptation investments and productive capital may lead to a reduced reliance on climate-sensitive industries.

In sum, even though the influences of climate change have mostly investigated on a national level, their implications have expanded to the international stage. The adoption of climate change mitigation measures often has positive effects that grow over time, and if these benefits increase faster than the costs of adoption, the diffusion of these measures is likely to accelerate across countries. This means that the longer a country waits to adopt climatic consequences, the greater the opportunity costs and the more difficult it may be to catch up with other countries that have already taken action (Adams, 2009: 80). This literature review about climate change adaptation has mostly shown that there is an increasing interest and debate on the international agenda across countries. Overall, the literature review suggests that there are many factors that can influence climate change adaptation, including socio-economic, environmental, institutional, and climatic factors. More importantly, it is increasingly common for governments to focus on developing a sustainable productivity and green economy to address the challenges of climatic effects. The diffusion and development of environmental products, jobs, technologies and implementations are expected to help mitigate climate change and reduce carbon emissions. In addition, recent policies aimed at promoting innovation in low-carbon technology may also stimulate technological innovation and economic growth more broadly. These initiatives, which are known as “green growth” initiatives, are based on the idea that investments in green technology and policy can have multiple benefits, including environmental and economic benefits.

2.2.3. Green Growth

The last strand in the literature considers studies of environmental-based growth. The phenomenon of green growth may illustrate the sustainability of any nation’s growth strategy. Green growth takes into account environmental and climate factors in its expansion strategy. Environmental sustainability, social inclusion, and economic growth are all goals that green growth aims to achieve. Facing some conditions like climate events, volatile food prices, water scarcity, and the loss of biodiversity, supports extending awareness of green growth. Besides, even if it is only indirectly responsible, globalization has contributed to the amplification of the significant environmental damage we are facing today.

Green growth is integral to sustainable development, and green technology adoption is a cornerstone of green growth policy. Green growth policies support a range of macroeconomic and microeconomic benefits, based on the simultaneous promotion of economic growth and environmental preservation (Adams, 2009: 21). These policies have also been shown to help reduce poverty and create new opportunities for the conservation of essential elements and the environment. It is believed that investing in green products and innovations can help generate higher profits for firms and countries, and that green growth activities can encourage firms and consumers to adopt more eco-friendly practices at the micro level (Baker, 2006: 8). Since green growth policies offer a way to reconcile economic expansion with environmental protection, they could have a big impact on long-term progress.

The Porter hypothesis proposes that environmental protection policies implemented by governments are closely tied to the development of green technologies and green growth. This theory suggests that embracing green technologies and promoting environmental-based growth can be an effective means for governments to tackle environmental issues and foster sustainable development (Adams, 2009: 115). Therefore, green growth, economic indicators, social and political factors, and environmental policies have been studied extensively in the literature. The quantity of green patents has been become increasingly important to researchers in recent years. Hoffmann (2015) explores the effects of population expansion, the creation of technology, economic growth, and policy restrictions on green growth. Based on the research, lower level of CO2 emissions, climate change mitigation, innovation, equal distribution, and structural adaptations are essential to the process of green growth.

Similarly, Popp (2012: 2) examines the impact of technology transition to the advancement of green growth through reduction of costs associated with green protection and the advocacy for green technology. He also emphasizes the significance of policy incentives, financial constraints, technological advancements, and research and development activities in fostering green growth.

Many studies in the literature on green growth have focused on its correlation with other variables. Likewise, Chang and Hao (2017: 498) examine the links between economic development, the environmental performance index, and the corruption index from 2002 to 2012. Based on their estimations, they find that progress in both areas positively impacts environmental efficiency. They conclude that environmental quality is also related to lower corruption, which supports economic growth. The impacts of CO2 emissions on sustainable productivity in Malaysia are studied by Chin et al. (2018: 190). According to their findings, CO2 emissions are a major factor in economic expansion. This study recommends that Malaysia's government closely observe the performance of its green growth policy to increase sustainable development. Comparable research by Zmami and Salha (2020: 469) examines CO2 emissions from 1980 to 2017 in light of economic development, urbanization, trade, investment, and energy consumption. Except for FDI, they discover no short-term causal link between any of the other components and CO2 emissions. However, their findings suggest that economic expansion, energy consumption, urbanization, and FDI all have beneficial outcomes over the long term. Ayamba et al. (2020: 25625) present the effect of FDI on environmentally-friendly growth from 1996 to 2016. This study's results suggest that investments have no appreciable long-term impact on environmental quality. Also, this finding suggests that while FDI may not have a lasting impact on environmental quality, it can be affected by pollution in the short term.

Moreover, Herman (2021: 1) focuses on the literature in the Global South to gather information on the interaction between green growth and technology innovation by employing citation, bibliometric, and keyword methods. The study concludes that environmental-based growth is a positive tool and has technological, environmental, and economic benefits for economic development. Furthermore, Baniya et al. (2021: 1) utilize energy and material consumption models to examine the improvements in the green economy in Bangladesh and Nepal from 1985 to 2016. From the results of energy and material consumption models, it is clear that Nepal and Bangladesh's economic growth cannot be enough for green development in an absolute sense of the current progress in energy and material productivity increases. From 1990 to 2018, Ochoa-Moreno et al. (2021: 1) analyze the interaction between CO2 emissions and FDI in Latin American economies from the perspective of environmental quality and environmental growth. Their findings disprove the existence of a near-term equilibrium state. However, investments in long-run equilibrium enhance CO2 emissions, which has an environmental quality concern. For the years 2000-2020, Hussain et al. (2022: 1) project how environmental technologies and indicators would affect environmental-based development in high GDP countries. According to their findings, green technology and the linear influence of GDP have a positive relationship with green growth, but energy consumption, level of CO2 emissions, and the nonlinear effect of economic performance decrease environmental-based growth. In addition, the results suggest that high-GDP level of countries might improve their sustainable productivity by prioritizing the expansion of environmental-based growth.

In line with this, numerous studies in the empirical literature, particularly in recent years, have underscored the factors that contribute to environmental approaches. From 1998 to 2011, You and Huang (2014: 1) estimate the indicators of environmental-based growth. Their data show that green growth in China has been rather slow. They forecast that the level of environmental-based growth in the future may enhance by encouraging innovations, green technology reforms, environmental quality, and environmental and resource productivity. Guo et al. (2015: 568) analyze the determinants of green growth (like the indicators of social economy, environment, resources, natural assets, and policy support) and entropy approaches. Their finding indicates that energy is not just the most influential component but also the key driver of sustainable productivity. Melichová et al. (2021: 1) estimate the factors of environmental-based growth and sustainability in the Slovak wood sector by using the survey method. Their result shows that pollution severely hinders eco-friendly progress. According to Frankel et al. (1991: 85), FDI has a disastrous consequence on sustainable productivity. This observation, however, runs counter to the work of Dean et al (2017: 1). Their research shows that FDI is crucial to China's path toward sustainable development.

Overall, the existing literature has been extended to include different methods to investigate green growth and its determinants. To illustrate the indicators of green total factor productivity (GTFP) in the context of technical, institutional, and structural changes, Chen et al. (2018: 1) use GTFP growth in China. Their empirical findings indicate that the GTFP declines by 0.02 percent each year on average and that it is improbable that environmental regulation will improve the GTFP. When the contribution of green productivity is to all industries' productivity, it falls well short of the aim of 50 percent. Also, Fang et al. (2021: 1) investigate the connection between the environmental pollution index and the GTFP in green economy. This study demonstrates that energy consumption, imports from other countries, and the rate of technology diffusion all have an impact on the effectiveness of the economy. These results imply that China's green economic success may hinge on the country's skill in handling these issues and embracing innovative technology.

The importance of advancing environmentally friendly technology, which are very helpful in the vast majority of low-carbon economies, has grown. Recently, researchers have significantly used number of green patents in their studies to provide environmentally friendly technologies. For instance, Samad and Manzoor (2015: 1) analyze the determinants of green growth using green innovations, patents, R&D expenditures, market size, and taxation in developed economies with fixed and random effect models from 1995 to 2010. Based on their findings, the impact of various factors on green technologies can be observed. Intellectual property rights are found to hurt green technologies. Thus, expenditures in R&D benefit environmentally friendly technology. Environmental taxation is determined to have a beneficial influence on the development of environmental technologies and products, and the scale of the market is seen as a favorable element.

The literature also aimed to determine how green growth affects the global economy in light of the threat presented to the global financial system by environmental performance and risk. Huang and Quibria (2013: 1) theoretically study the influence of innovation and finance on the green growth process by deriving the Green Solow growth model and they also empirically estimate the green growth index in 42 countries from 1990 to 2009. In addition to validating the importance of government policies, financial performance, and external shocks in managing green development, their theoretical and empirical findings show that there is convergence of environmental-based approaches amongst nations in the sample.

Moreover, Jadoon et al. (2021: 533) explore the impact of environmental-based growth in the stability of the financial sector between 2010 and 2015. According to their estimations, green growth contributes to national financial security. Therefore, the development of green growth contributes to creating financial stability and reducing environmental and financial risk. The effects of ICT-trade and bank financing for green growth and carbon neutrality from 1996 to 2019 are then analyzed by Bo et al. (2022: 1). Their empirical results show that ICT-trade, economic and environmental performance, education level, R&D spending, and green growth all contribute to reducing CO2 emissions. Their findings not only demonstrate sustained interest, but also point to potential drivers for promoting green growth in countries all across the world.

Considering this literature, there are a few studies that discuss the interactions between poverty mitigation and green growth. According to Dercon (2014: 2), poverty mitigation is a key economic growth target for low- and middle-income nations, green growth must also be compatible with this goal. They emphasize the need of ensuring that the transition from economic growth to green growth does not increase poverty, even if it may not increase overall economic output or well-being.

In light of the prior empirical literature, despite the fact that many researchers have devoted considerable time and energy analyzing how environmental laws affect sustainable growth, they have reached conflicting findings. Yuan and Xiang (2018: 895) also investigate the influence of laws on technology innovation and environmental-based development using panel data of Chinese manufacturing sectors between 2003 and 2014. Their research shows that environmental regulations discourage spending on research and development and the creation of new patents. While green factor productivity has improved in the long term, they find that environmental rules have boosted labor productivity in manufacturing, energy, and environmental outputs. Moreover, their study indicate that environmental regulation has improved energy output. The impact of environmental restrictions on green productivity is presented by Li and Zhao (2021: 1247). It is clear from their results that green productivity shows a causal spatial relation for the period analyzed. They find that green productivity turns positive after the inflection point and environmental rules can influence green productivity positively via innovations in technology and investments. Their findings have significant implications for future green growth policymaking. Later, Xu et al. (2021: 55302) explore the impacts of environmental regulations and investments on environmental patent data for different manufacturing sectors based on environmental-based growth using the fixed effect model. According to their findings, green growth technologies can be improved with environmental regulations and investments.

Understanding the economic possibilities and ramifications of transitioning to a more sustainable productivity is made possible by the theoretical literature on environmental-based indicators and green growth. In their analysis, Brock and Taylor (2010) factored in demographics, CO2 output, and the proportion of GDP spent on investments. The Green Solow Model was designed as an updated version of the original Solow model that assumes the benefits of sustainable productivity and technologies.

Likewise, Hallegatte et al. (2012: 1) investigate the foundations of environmental-based model and discuss green policies and implements in the context of environmental benefits. They conclude that the progress of green growth is connected to decreasing and preventing pollution in the short-run, increasing investments in environmental quality protection, decreasing environmental degradation, and increasing environmental performance. Jacobs (2012: 3) contributes to identifying the idea of green economy and its interaction with environmental sustainability. He offers important results for enhancing the priority of green policies in the context of investments and technological innovations. As a result of the growth theory, to get the economy on the best development path, he emphasizes the need for green measures. He also asserts that green policies can develop sustainability with taxation arrangements.

Green growth approaches have begun to take place of sustainable development arguments in the national and global areas. In fact, Scrieciu et al. (2013: 251) argue that traditional economic equilibrium and optimization theory provide meaningful basics on green growth assertions. In contrast, they have focused on data from real-world applications that demonstrate the impact of macroeconomics on environmental expansion. It is crucial to learn from these research that carbon-intensive energy usage is the major foundation for GDP growth. Therefore, the quality of the environment, uncertainty, and policy interventions on green growth may need to improve significantly.

A green growth process can accelerate growth based on a neoclassical growth model by boosting the availability of capital that substitutes for depletable natural resources. It can be envisaged from the green growth theory that environmental policies affect sources of growth and investment. Smulders et al. (2014: 423) explore green growth in an optimal equilibrium depending on a literature review of economic and ecological challenges in recent years. They find that initial circumstances can have a significant impact when it comes to determining the best growth path. Environmental measures do not appear to have a significant beneficial influence on income growth or a seamless transition to a "green steady state," according to their results. There are both advantages and disadvantages to shifting to a green economy. Even when the environmental damage level is unchangeable, the efficient transition process may be in stages. Accordingly, a range of different arrangements may appear simultaneously, even along an optimal path, such as countries reducing their reliance on fossil fuels while others continue to grow, although more slowly.

From a theoretical perspective, Radu (2016: 1) uses the impact of information and communication technologies (ICT) on the environment and indicates the general and specific drivers such as economic, ethical, and regulatory factors that positively affect green ICT adoption. The study demonstrates that adopting green ICT relies on benefits and investments, which are resource efficiency, reduction of e-waste, rising recycling, and delivering fewer CO_2 emissions. Another study by Loiseau et al. (2016: 361) identifies various theories, concepts, approaches, experiments, and tools in the concept of environmental-based growth and sustainable productivity to debate the links between green economy and sustainability. They offer a fresh perspective on the interrelated ideas of ecological, financial, and social sustainability.

In the recent studies, Capasso et al. (2019: 390) provides a survey of 113 recent articles to explore the connections between innovation, environmental matters, economic performance, and environmental factors. The findings of the survey underline the need for new technologies, new formal institutions, a theory-based approach, well-designed knowledge systems, and government systems to estimate environmental developments independently and to eliminate the barriers and challenges to green growth. Söderholm (2020: 1) discusses some of the challenges to the progress of sustainable technology change and promotes the redistribution, development, and adaptation of innovations, sustainable environmental policies, and sustainable technology change. Lastly, Sulich (2021: 6861) identifies indicator of green growth and concludes that innovation has a significant role in building a competitive approach. In fact, the study argues that these factors may promote the development of environmental-based approach by reducing environmental hazards, increasing social reliability, providing corporate responsibility to investors, reaching easily renewable resources, and enhancing sustainable consumption.

The findings presented by previous studies acknowledge that governments have a crucial role in promoting green growth, which necessitates essential adjustments to the development plan. In addition, rising social fairness may be seen as a source of sustainable development. As a result, green growth depends on factors like encouraging economic expansion, advocating environmentally friendly legislation, and ensuring social inclusion. Some of these findings are present in empirical studies (Hoffmann 2015; Chang and Hao, 2017; Chen et al., 2018; Zmami and Salha, 2020; Fernandes et al., 2021; Jadoon et al., 2021) and some are given evidence from theoretical studies (Loiseau et al., 2016; Georgeson et al., 2017).

Indeed, environmental degradation and weather conditions resulting from climatic effects pose additional challenges to the transition towards green growth. The finding is consistent with the studies (Chang and Hao, 2017; Chin et al., 2018; Yuan and Xiang, 2018; Li and Zhao, 2021; Xu et al., 2021; Hussain et al., 2022). Policy initiatives that encourage the development and dissemination of green technology to combat environmental issues and advance sustainable development have also been emphasized by these studies. By embracing green technology, societies can mitigate the environmental impacts of economic activities and contribute to long-term sustainability.

In conclusion, there has been a lot of focus on environmental-based growth, innovations, technological development, and dissemination in recent years. Green growth also emphasizes innovation and sustainable development. Previous studies present a reasonable framework to investigate and compare differences in environmental and economic performance among nations with empirical findings and theory-based approaches. Based on this, the current literature review comes to the conclusion that economic growth, open trade, foreign direct investments, the development and spread of green technology, green patents, environmental quality and regulations, adapting to climate change, financial stability, reducing poverty, and government incentives can all speed up the improvement of green growth. In contrast, increasing CO2 emissions and energy use, air pollution, and corruption result in declining green growth. In this sense, environmental and low-carbon technologies and resource efficiency are critical to supporting green growth from a global political economy standpoint.

From this background, it is important for the fields of dissemination of environmental technologies and concerning climate change technologies to be managed to encourage the development of environmental technology and low-carbon development. Policymakers in developing countries are increasingly recognizing the need to shift to domestic green growth policies that prioritize economic growth without causing negative environmental impacts. To be successful, green technology innovations should reduce industrial costs and improve production rates that align with long-term development goals. Therefore, green policies should be viewed from a long-term perspective, and policymakers and entrepreneurs should implement them with a focus on the sustainable economy. Thus, environmental sustainability, social inclusion, and economic growth are all goals that green growth aims to achieve.

2.3. THEORETICAL FRAMEWORK ON GREEN GROWTH

This section introduces a basic model that explores the connections between income level and green outputs, specifically pollution. There has been a lot of discussion on the connection between sustainable productivity, economic progress, and environmental protection. A central concept in this discourse is that of environmental-based growth. The early use of the term “green growth” stood for a green economy, climate change conditions, and adaptation to green innovations and investments (Adams, 2009: 22). In 2005, Asia and the Pacific nations pioneered the notion of environmental-based growth model. The concept of green growth has made substantial progress in recent years. It refers to an economic expansion that could shift from the current state of affairs to one that is more environmentally friendly. In this sense, it encourages economic development while minimizing waste, pollution, emissions, and the consuming of essential elements; it also improves energy efficiency, safeguards biodiversity, and the local ecology. Therefore, a country’s economic, social, technological, environmental, and developmental components can all benefit from a comprehensive set of green growth strategies. This is for sustainable development that is becoming increasingly popular as a model for economic growth. Sustainable development necessitates developing green economies and green growth models in an economy due to the links between ecological, environmental, monetary, and social factors. While discussions on green growth have been prevalent in political circles, the academic and international organization spheres have also actively engaged in theoretical and practical conversations on the subject. The Korean government launched one such project in 2010 when it founded the Global Green Growth Institute (GGGI). Serving as a forum for advancing green growth, the GGGI became the first global organization to prioritize the green growth agenda in 2012. Governments throughout the world are increasingly employing the environmental-based knowledge to advocate for environmentally friendly economies. Supportively, everyone can be a part of the social development that is wanted if “green growth” depends on essential elements and their protection or renewal via effective expenditure (Dinda, 2013: 1).

As is well known, in the field of economic performance and policy, Solow’s (1956) study has been recognized as neoclassical growth model. Solow infers that once the long-term equilibrium (steady-state) is reached, the growth rate of the economy’s product per capita can only be kept up if technology keeps getting better. In the 1950s, economist Robert Solow proposed a neoclassical model of economic development based on the theory that increased productivity and population expansion are the primary factors in a booming economy. The model assumes that technology is exogenous (i.e., not influenced by economic factors) and that the production function is subject to decreasing returns to capital (Solow, 1956). In Solow’s neoclassical growth model, long-run economic growth results only from exogenous technological change and population growth. As an exogenous growth model, however, the Solow model has been criticized for its inability to capture the unique characteristics of the technological innovation process. Additionally, in the Solow model, technological development includes non-economic phenomena such as better management organization and education that raise the level of skill, but not the contributions arising from the increase in labor and capital inputs. According to Romer (1990: 71), technology is neither a conventional good nor a public good; rather, it is a non-rival, relatively excludable good due to its unique characteristics as an input. The Romer model assumes is that there is no human capital stock, savings are exogenous, and technological progress is endogenous. In another study, Steger (2002: 1053) combines productive consumption with the growth model. This research contributes to our understanding of how investments in essential elements may foster long-term prosperity.

Since the development of the neoclassical Solow model, there have been a number of efforts to incorporate environmental considerations into economic growth models. One such effort is the Green Solow model, which is an extension of the neoclassical Solow model that includes an environmental quality factor in the production function (Hall, 2009: 11). Environmental-based model acknowledges that deterioration of the environment can reduce the sustainable productivity and labor and that improvements in environmental quality can increase productivity (Adams, 2009: 101). Other approaches to integrating environmental considerations into economic growth models include the EKC model and the Sustainable Development Goals (IEA, 2022). These models and frameworks recognize the importance of taking into account environmental considerations in economic growth strategies and offer a foundation on which to build green growth initiatives.

The theoretical framework of green growth encompasses several important factors (Jacobs, 2012: 1). Firstly, it recognizes the interdependence of economic performance and environmental sustainability. This means that income level relies on the accessibility of essential resources and a healthy environment, while environmental degradation can hinder economic growth by depleting resources and raising environmental protection costs. Another crucial factor is the role of environmental-based technologies and achieving growth model. Green technology encompasses environmentally friendly and resource-efficient technologies that can mitigate environmental impacts and enhance resource efficiency. By embracing and implementing green technologies, societies can promote sustainable economic growth.

Green technology diffusion refers to the process of introducing and adopting green technologies within a society or economy (Halls, 2009: 10). Green technology diffusion reduces environmental impacts and improve resource efficiency, contributing to a sustainable productivity. The diffusion of green technology is often seen as a key component of green growth strategies, which aim to foster economic growth while minimizing negative climatic impacts. Furthermore, green technology is determined by the fact that it reduces environmental degradation as compared to the current state of affairs. The primary focus is on enhancing environmental protection, which sets it apart from standard innovation techniques. Since the works of Pigou (1921) and Coase (1960), there has been significant discourse among economists regarding the consequences of green externalities, such as economic performance and the effectiveness and efficiency of the methods accessible to public policymakers for resolving these problems.

More recently, Steffen et al. (2015: 1) have shown that human activity is the primary driver of non-green growth and that the consumption levels of the upper classes have the greatest effect on the environment. An environmentally friendly approach to economic performance is the primary goal of green growth, which is achieved through the development of environmentally-friendly products and services, as well as the utilization of ecological elements. Because of that, the transition to sustainable product focuses on emissions that are generated by the production and demand of industrial products. Even though sustainable use of natural resources cannot be directly achieved through economic growth, green growth can have a direct causal link with economic performance (Fernandes et al., 2021: 2026).

From a theoretical point of view, some of the earlier studies proposed models that examine the dynamic impacts of the green growth model on economic performance and sustainable productivity. One of the pioneers is Brock and Taylor (2010: 127), that develops the Green Solow model on CO2 emission patterns and their mechanisms as a structural extension of the Solow model. In fact, they use the neoclassical Solow growth model to ground their research on how economic activity affects carbon emissions. Therefore, they examine the links between the EKC and the Solow model using pollution and income per capita factors. Huang and Quibria (2013: 1) conduct a Green Solow model to identify the effects of ecological, economic and technological factors on the process of green growth. Their model builds a theoretical framework for green growth and determines how environmental, social, and economic factors affect green growth.

In the 21st century, the issue of climatic effects has emerged as a significant threat to the preservation of natural resources. These assets are vital to the maintenance of economic expansion and development. Sustainable development is the goal of Dinda's (2013: 1) theoretical model for green growth, which focuses on the enhancement of essential elements. The theoretical model assumes that decreasing waste, pollution, and greenhouse emissions, protecting biodiversity and the ecosystem, and preserving natural resources can promote sustainable development and economic growth. Other research by Dinda (2013: 1) examines how natural assets regenerate and provides theoretical evidence for a green growth model in India. The research points to productive consumption in an inclusive green growth framework that protects natural assets in the economy and also helps the economy grow. More specifically, the study advocates that sustainable development can be achieved through inclusive green growth. Stefanski (2013: 1) introduces pollution accounting in the green growth theoretical framework using economic performance and level of CO2 emissions. Based on the theoretical analysis, he suggests that what drives emissions in the Green Solow model is a combination of decreasing economic performance due to convergence and constant abatement of technological achievement rates. Later, Ho and Wang (2014: 14) discuss low-carbon green growth connection with environmental preservation and economic growth in China. Low-carbon green growth involves reducing energy consumption, increasing resource efficiency, and transitioning to low-carbon energy sources. They point out the theoretical literature on environmental degradation, environmental regulations and their costs, green policies, and economic growth. There are potentially two channels through which lowering emissions helps GDP expansion. First, it can improve the economy as a whole by boosting the supply of and return on natural capital through the input effect. Consequently, with increased health and longer life expectancy, a higher standard of living is achieved when environmental quality is enhanced. In addition, stricter regulations about pollution might spur development of new products. Porter (1991) and Porter and Van Der Linde (1995) disprove the common belief that laws add costs to businesses, which may make them less competitive in the global market. Lastly, Acemoglu et al. (2014: 1) describe a development model with endogenous and directed technological change under conditions of environmental constraints and few resources. Using dynamic tax policy, market size, and pricing effects, their theoretical paradigm promotes long-term growth while also maximizing intertemporal welfare.

Overall, the studies mentioned above emphasize the importance of an optimal green growth path. In addition, Smulders et al. (2014: 1) demonstrate an optimal growth path in interaction with economic performance and sustainable productivity and conclude that there is no guarantee of a “green steady-state” along a balanced path. There can be a wide range of concurrent adjustments along an ideal path that affect the greenness of an optimal development path. Guilló and Magalhaes (2018: 2) extend the analytical framework for green growth and long-run sustainability. They conclude that rapid advancements in innovation can keep pace with the deterioration of air quality and nonrenewable resource-fueled growth in the long run.

Fankhauser and Tol (2005: 2) explore the dynamic impact of climatic effects on economic development using saving and capital accumulation effects with a simple climate-economy model. When the technological transition is endogenous and the saving effect is reduced, they conclude that the capital accumulation effect has a huge and significant impact on climate change. Moreover, the study on the different growth models, such as the Solow-Swan model, the Ramsey-Cass-Koopmans model, the Mankiw- Romer- Weil model, and the Romer model to distinguish between capital accumulation and saving (Baker, 2006: 12). They also find that the Mankiw-Romer-Weil model contributes to climatic effects on economic performance by taking into account in their theoretical analysis. They find that the impact on growth rates is rising with time as the dynamic effects take hold. However, the influence is insufficient to alter the projected path of long-term growth to one of persistently negative growth and recession. Indirect pollution abatement techniques for environmental protection are becoming increasingly important as the problem of dispersing pollutants into the natural environment gains prominence (Adams, 2009: 52). Therefore, developing an analytical framework for green technology diffusion and green growth can be important for designing national policies, preferences, and resources at the diverse stages of sustainable development. Following next, we will apply the empirical version of the Green Solow model to make a contribution to structural and reasonable determinants in fostering green growth. Accordingly, the model of diffusion curve and the Green Solow model are introduced in this section by deriving some testable implications regarding the impacts of emissions, environmental degradation, and pollution abatement on the growth and development process.

2.3.1. Technology Diffusion Model

Technological progress is a major driving force behind economic growth. Many researchers, including the pioneering studies by Solow (1957) and Abramovitz (1958), have found that technical development is crucial to economic expansion. More importantly, new technologies require time to integrate into economic activities. It must first be implemented into the economy (innovation). Subsequently, many individuals begin to accept it (diffusion). Diffusion is equally as vital as innovation. In order for newly developed technologies to have an effect on the economy, they first need to become widely used. The process of diffusion is not a simple one, and it typically takes a definite amount of time. The understanding of the sluggishness of the technology diffusion process has been examined by diverse disciplines (Halls, 2009: 3). Two key forces have been identified. To begin with, there are a wide variety of people who might be interested in adopting a certain technology; this means that even if the technology is superior in general, everyone may not find it to be an improvement.

Second, implementing new technology is a high-stakes endeavor that necessitates a great deal of detailed knowledge.

Both the innovator and those who benefit from their work participate in the creative process. Oftentimes, it takes some time for technological defects to be ironed out of an innovation's first iterations. Improvements made to a novel technique or product may be almost as significant as the new concept itself during the early phases of the dissemination process. Researchers have recognized the good approximation that S-shaped curves, like the logistic, contribute to the process of technology diffusion as assessed by the vast margin ever since Griliches (1957). The logistic curve is represented by:

$$Y_t = \frac{\beta_1}{[\,1 + e^{-(\beta_2 + \beta_3 t)}\,]}$$

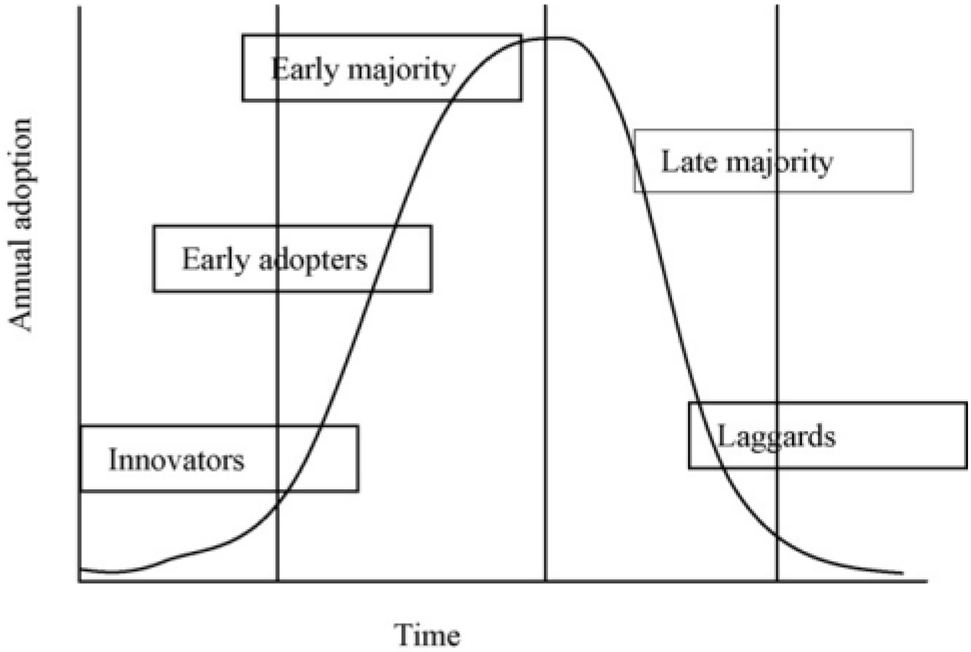
where *t* stands for time, β_3 for the rate of adoption, β_2 for the integrating constant that places the curve on the time scale, and β_1 for the long-run result.

In most cases, new technology progress pursues a sigmoid or “S-shaped” path over time by potential adopters, increasing slowly at first, then experiencing a period of very rapid growth, and finally slowing down as the technology achieves maturity (Geroski, 2000). The epidemic model, proposed by Griliches (1957). suggests that the primary factor that determines the spread of a new technology is the availability and dissemination of information about it. According to this model, the most effective way for a technology to become widely adopted is for it to be embraced and demonstrated by individuals or businesses that have already adopted it, as they can serve as sources of information for others interested in the technology (Griliches, 1957: 505). Therefore, technology enables contact between the infected population and the uninfected population catalyzing adoption. The differential equation, $df/dt = \beta\, f(1-f)$ is derived by denoting the proportion of the potential utilizing the chosen population as *f*. This equation’s solution is a logistic function with the characteristic S-shaped curve. A new technology's “contagion,” as measured by a particular metric, is likely affected by its price and the degree to which it improves upon the technology it supplants (Geroski, 2000: 605).

The probit model emphasizes that individuals or businesses adopt new technologies based on their calculations of the maximum value they can gain. This model does not necessarily assume that the slow adoption of new technologies is inherently inefficient. In contrast, the epidemic model suggests that each adopter of a new technology generates a positive effect on society by sharing information about it with other potential adopters. This can lead to the conclusion that adoption rates under a “laissez-faire” approach, in which individuals or businesses are free to adopt new technologies at their own pace, may not be optimal from a societal perspective. According to the epidemic model, the diffusion of technology the consequence of both the spread of understanding about it and the technology’s improvements over time, making it more appealing to potential adopters.

There are five stages of the diffusion model as shown in Figure 1, such as awareness, interest, evaluation, trial, and adoption (Rogers, 1995: 242). Since the introduction of technology to the market, there have been four distinct groups of consumers who have adopted it at different rates: the innovators/early adopters, the early majority, the late majority, and the laggards. However, it is often difficult to predict the rate and extent to which technology will be adopted. As an example, it took 40 years for the technology of nuclear fission to be used in a commercial power reactor, providing 20% of the United States’ electricity (Robertson, 1971). This demonstrates that the adoption of technology can take a long time and may not follow a predictable pattern.

Figure 1: Diffusion Curve by Adopters and Timing



Source: Rogers, 1995.

Figure 1 illustrates how early adopters of new technologies are typically higher risk-takers, in line with the diffusion of innovation idea. These individuals often have access to capital and are able to easily understand technical information. They can serve as opinion leaders, sharing information about the innovation with others who have not yet adopted it. On the other hand, those who wait until an invention has gained universal acceptance before embracing it are more likely to be suspicious and cautious, missing out on the network externalities that early adopters enjoy. Those that wait to accept a new technology are often more conservative and less financially stable than the early adopters (Rogers 1995: 264).

Most of the research that has been conducted green growth concepts. The literature on the adoption and spread of new technologies proposes that the role of suppliers, including the government, may be particularly important in the adoption and diffusion of environmentally friendly or “green” innovations. However, most of the current research overlooks the significant role of the diffusion of technologies as they are applied. However, Galor and Tsiddon (2017) stand out as an essential exception. They have studied how the increased availability of technology has impacted various aspects of society, such as income inequality, intergenerational mobility, and GDP growth. They have also explored external factors that may have contributed to the increased accessibility of technology. Specifically, the rate at which these technologies spread is affected by a number of different factors, including socioeconomic factors, technological factors, and institutional factors. More importantly, the government may have a greater effect on the adoption of environmental factors, particularly in the early stages of diffusion, compared to other types of innovations.

2.3.2. Green Solow Model

Green growth may be understood by applying growth theory to the problem of environmental deterioration and the policies put in place to address it, as well as to as well as to the drivers of economic expansion and the returns on investment. The theory may illustrate how economic and environmental trade-offs result from the theoretical framework and identify which processes and policy trade-offs might be minimized. In the classical Solow growth model (1956), there are three basic components. Labor-enhancing technology (knowledge) (A), physical capital (K), and labor (L) are used to produce output (Y). Growth in A can show technological change, including improvements in structure and methods, and development in the social capital accounts. In this classical growth theory, the environment has no productive role. The following is a standard description of the association:

$$Y = f\,(A, K, L) \tag{1}$$

Growing production variables K and L (with $dY/dA > 0$; $dY/dK > 0$; $dY/dL > 0$) along with increasing productivity. A refers to output growth dY/dt. Increasing population, more labor force participation, and better conditions for health and education all contribute to a rise in labor. In growth models, some portion of the output is used to enhance the capital stock, K:

$$Y = C + I \tag{2}$$

$$dK/dt = I - \delta K \tag{3}$$

where C stands for consumption, I for investment, and δ stands for the deterioration and obsolescence of capital assets. Change in A can be attributed to improvements in technology, as well as a rise in social capital and alterations in organization and practice.

As in the Solow model (1956), labor and total productivity increases are exogenous in growth theory models. Alternatively, productivity growth in other models, such as Arrow, (1962), Lucas, (1988), Romer, (1990), Mankiw et al., (1992) is endogenous and based on investments in human capital such as education and R&D investments as well as the size of output and the ability to learn through experience. Economic policy and economic growth can impact the accumulation of physical, social, and human capital in order to optimize production or maximize the rise in output. Although the environment can be included in the utility function through its relative value, it plays no significant role in this method. Given that the environment converts to natural capital, environmental degradation, and natural resource depletion constitute a capital loss. At least since Malthus, the assumption that economic output is closely linked to the stock of natural resources and the condition of the circumstances has been widely adopted (Malthus, 1798).

So far, an investment in environmental arrangements is just as valuable as a physical capital investment that promotes growth in the economy. When environmental arrangements fail, natural capital depreciates and decays, which has a direct influence on the output. Thus, environmental factors have become an essential component of natural capital. When properly implemented, the cost and benefits of environmental management are on a par with those of investing in physical capital. To show these implications explicitly, the production function can be extended with E as follows:

$$Y = f(A, K, L, E) \tag{4}$$

where E shows the natural (environmental) capital (with $dY/dE > 0$). Sustainable development in terms of total capital growth consists of continuously developing economic capital (K), social capital (L), and natural capital (E). This trend is sustainable for future policies.

As a means of measuring green growth's impact, it is necessary to incorporate market failures and the fact that the economy is not in steady-state equilibrium into growth models. Maximum efficient output is substituted for the production function. This means producing as much as possible with the resources at hand while minimizing waste. The real output may be described as follows:

$$Y = \beta f (A, K, L, E) \tag{5}$$

where β has a number between 0 and 1 that measures the production efficiency. The second alteration is adding P_e, which can be seen as an effort to protect the environment and environmental policies:

$$Y = \beta (P_e) f[A(P_e), K(P_e), L(P_e), E(P_e)] \tag{6}$$

The above equation states that environmental policies have the potential to generate positive approaches to economic production through the expansion of productive capital (K, L, and E), the advancement of efficiency (y), and the acceleration of technological growth (A).

This equation describes the interplay between capital accumulation, technological progress, environmental quality, and economic output in the Green Solow model. The model emphasizes the need to balance economic growth with environmental sustainability by considering the impact of environmental quality on production and incorporating policies that promote environmental technologies, resource efficiency, and environmental conservation.

Brock and Taylor (2010) study the growth accounting of the standard Solow model (1957) and make the assumption that higher output is linked to higher emissions. Also, they use an improved version of the Solow model to look into the simple analysis of the EKC, which says that improvements in technology exogenous to the economy lead to steady growth and better environmental quality. Both savings and abatement options are set exogenously in the simplest model. When using the

Solow model, it's typical to assume a fixed savings rate. The assumption of a constant intensity of abatement allows us to highlight the better impact of declining returns and technological shifts in developing an EKC. Besides, a change in environmental legislation might have a substantial effect on emission levels and peak emission time, as evidenced by the fact that the intensity of abatement has changed. In a simple way to analyze the output and emissions relations at a constant time t in an economy, we can write the pollution production function as follows:

$$P_t = N_t Y_t \tag{7}$$

where P_t indicates the total emissions of an economy, N_t is the number of emissions emitted per unit of output and Y_t represents the total output of an economy. The links between the growth rate of emissions, $g_{P,t}$, the growth rate of emission intensity, $g_{N,t}$, and GDP growth, $g_{Y,t}$, are derived by using time-dependent differentiation and taking logarithms:

$$g_{P,t} = g_{Y,t} + g_{N,t} \tag{8}$$

As stated in equation (8), emissions increase by time if and only if $g_{P,t}$ is greater than zero and decrease if and only if $g_{P,t}$ is less than zero. Therefore, an EKC can only appear if $g_{P,t}$ declines from above zero to below zero over time. If either $g_{Y,t}$ or $g_{N,t}$ (or both) decreases over time, then $g_{P,t}$ can drop as a result. Due to exogenous technological advancements in abatement technology, Brock and Taylor (2010) suppose that $g_{N,t}$ stays fixed and negative, and also demonstrate that a reduction in $g_{Y,t}$ caused by capital accumulation is the driving force behind the fall in $g_{P,t}$.

For the sake of simplicity, both savings rates and pollution abatement options are considered to be exogenously determined. With the assumption of continuous returns to scale and a concave production function, $F(K_t, B_t L_t)$, is assumed to produce output using capital (K_t) and labor (L_t), with B_t representing the productivity of labor. At a set savings rate s, capital is accumulated and depreciates at a constant rate, δ. Moreover, pollution is a direct result of manufacturing processes. The impact of pollution on the output means that each unit of economic activity F, produces Ω_t units of pollution. Also, γ refers to the fraction of economic production given to pollution abatement at any constant and exogenous point. A unit of output generates $a(\gamma)\Omega_t$ units of pollution after the abatement, where $a(\gamma)$ is an abatement function assumed to fulfill a (0) = 1 and $a'(\gamma) < 0$ and $a''(\gamma) > 0$. Therefore, abatement has a somewhat beneficial but declining marginal effect on pollution reduction. It is expected that the labor force, L_t, will increase at a constant rate, *n*. It is also assumed that labor productivity, B_t, grows at a constant and exogenous growth rate, g_B. In the model as mentioned, the abatement expresses the amount of pollution mitigation as a growing and strictly concave function of the total output growth (Brock and Taylor, 2010: 135). The abatement progress can also be attributed to exogenous technological advancement which decreases, Ω_t, at a fixed rate $g_A > 0$. To connect the assumptions regarding pollution and abatement to the Solow model, we can observe the relationship between the output available for consumption or investment, Y_t, becomes $Y_t = (1-\gamma)$ F when abatement is considered. The model is provided by:

$$Y_t = (1-\gamma)\,\mathrm{F}\,(K_t, B_t L_t) \tag{9}$$

$$\dot{K}_t = sY_t - \delta K_t \tag{10}$$

$$P_t = a(\gamma)\Omega_t\,\mathrm{F}\,(K_t, B_t L_t) \qquad (0 \leq \gamma \leq 1) \tag{11}$$

$$L_t = n\,L_t \qquad B_t = g_B B_t \qquad \Omega_t = -g_A \Omega_t \tag{12}$$

where a dot denotes the partial derivative of a variable with respect to time. Notably, observe that emission intensity, denoted by $N_t = P_t\,/\,\mathrm{F}\,(K_t, B_t L_t)$, decreases at the fixed exogenous rate of technological development in abatement, g_A, which is independent of the amount of abatement, γ. These expressions can be seen in the following equations by substituting (11) and (12) in equation (7), which would give:

$$P_t = a(\gamma)(-g_A)\,Y_t \tag{13}$$

Then, dividing both sides of this equation by Y_t would give:

$$N_t = a(\gamma)(-g_A) \tag{14}$$

The equations (9 -12) above summarize the key results of the first deviation from the standard Solow model that assumes pollution is produced with every unit of output. A second deviation is based on the presumption that a portion of income can be allocated to pollution control measures and abatement (Brock and Taylor, 2010: 135). Nevertheless, the dynamics of the standard Solow model are not affected by either of these assumptions. Moreover, the generation of pollution has no effect on output growth, whereas the degree of pollution abatement will alter the level of economic growth but not its growth path. To solve the green Solow model like the standard Solow model, the production function in equation (9) and the capital accumulation function in equation (10), can be rewritten as following equation in terms of effective units per capita by respectively assuming:

$$y_t = \frac{Y_t}{B_t L_t}\ ,\ k_t = \frac{K_t}{B_t L_t} \text{ and } p_t = \frac{P_t}{B_t L_t}$$

$$y_t = (1-\gamma)f(k_t) \tag{15}$$

Then, equation (15) is derived from equations (10) and (12) to obtain the modified version of the so-called fundamental Solow equation of motion where $f(k_t) = F(k_t, 1)$

$$\dot{k}_t = s\,(1-\gamma)f(k_t) - (\delta + n + g_B)k_t \tag{16}$$

$$p_t = \Omega_t\, a(\gamma)\, f(k_t) \tag{17}$$

Equation (16) reveals that capital per unit of the effective worker increases as the quality of the environment increases. For the sake of simplicity, assume that $F\,(K, L) = K^{\alpha}\, L^{1-\alpha}$. Suppose the Inada conditions are kept for each unit of economic activity (*F*) when γ is constant, it is that beginning from any *k (0)* > 0. Thus, the economy converges to a steady-state solution, a unique level of capital per effective worker, k^*, like in the standard Solow model. Aggregate output, consumption, and capital all expand when the economy finds a sustainable growth path of $g_Y = g_C = g_K = g_B + n$, whereas their per capita values increase at a rate of g_B. By definition, the standard notation of growth in per capita can be rewritten $g_y = g_c = g_k = g_B$ along the balanced growth path. Lastly, note that in equation (17), when k converges to a constant, k^*, the growth rate of emission, g_P, rises with respect to the given by:

$$g_P = g_B + n - g_A \tag{18}$$

Since total output increases at a rate of $g_B + n$ throughout the balanced growth path, the first two phrases in (18) indicate the scale effect on total emission growth. The second phase is a result of technological advancements in pollution abatement as a technical effect. However, sustainable growth is described as growth that is both economically and environmentally beneficial. The following equation (19) points out that there are factors that ensure long-term sustainable growth:

$$g_B > 0 \qquad \text{and} \qquad g_A > g_B + n \tag{19}$$

In order to raise GDP per capita, industrial technology must improve. In order to help the environment and minimize pollution, technological advances in pollution abatement must increase at a faster rate than output overall. Once again, the economic growth rate and emissions are calculated using a Cobb-Douglas formulation ($F\ (K, L) = K^{\alpha}\ L^{1-\alpha}$) with a constant capital share, α, with 0 < α < 1. Following the same steps for a steady-state solution, (k^*) , as in the standard Solow model is given by equation (21). To do this, note first that (20) can be rewritten in terms of capital per effective worker as below:

$$\frac{\dot{k}_t}{k_t} = s\ (1-\gamma)k_t^{\alpha-1} - (\delta + n + g_B) \tag{20}$$

$$k^* = [s\ (1-\gamma)\ /\ (\delta + n + g_B\ )]^{1/_{1-\alpha}} \tag{21}$$

where the more increased the fraction of output dedicated to abatement, the lower the steady-state k^* is. As k^* decreases, the steady-state per capita income declines. Nevertheless, this has no effect on the growth rate in a steady state. To get the growth rate of emissions, taking the derivative of equation (18) with respect to time (t) would give:

$$\frac{P_t}{P_t} \equiv g_{P,t} = g_{Y,t} - g_A \tag{22}$$

$$\frac{P_t}{P_t} = \left(g_B + n + \alpha \frac{\dot{k}_t}{k_t}\right) - g_A \tag{23}$$

where $g_{Y,t} = g_B + n + \alpha \frac{\dot{k}_t}{k_t}$ shows the growth rate of output off the balanced growth path. $g_{P,t} \equiv \frac{\dot{P}_t}{P_t}$ refers to aggregate emissions and $\alpha \frac{\dot{k}_t}{k_t}$ stands for the growth rate of capital per effective worker. Capital accumulation can now be connected to the outcome of pollution levels by using these two expressions (20) and (23).

Then, substitute (20) into (23) to investigate the drivers of emissions and income per capita at the peak where the EKC obtains its maximum level, and we can rewrite the capital per effective worker, (k^{**}), as follows:

$$\frac{P_t}{P_t} = g_B + n + \alpha\,[(s\,(1-\gamma)k_t^{\alpha-1} - (\delta + n + g_B)] - g_A \tag{24}$$

$$k^{**} = \left[\frac{s\,(1-\gamma)}{\delta + n + g_B - g_P/\alpha}\right]^{1/(1-\alpha)} \tag{25}$$

In sum, the theoretical model presented in this section reveals the fact that:

$$k^{**} < k^* .$$

The accompanying formula shows that the EKC is a natural consequence of the Solow model. It also illustrates those domestic actions, such as increased expenditure on pollution abatement or technical improvements in investments in green technologies, can speed the transition to a greener phase of the EKC.

Similarly, as in the Solow model, the effective-units economy begins with a capital stock that is less than the steady-state level ($0 < k_0 < k^*$), and it accumulates capital ($\frac{\dot{k}_t}{k_t} > 0$) until it converges to the steady-state ($\lim_{t \to \infty} k_t = k^*$), at which time it ceases to capital accumulation ($\lim_{t \to \infty} \frac{\dot{k}_t}{k_t} = 0$). Also, while the variation of capital accumulation drives the model's determinants, the only impact of capital accumulation is its influence on economic growth rates. As a result, the economy is growing faster outside of the balanced growth path than within it. Moreover, conditions give the following relations at steady-state equilibrium, as defined k^{**} is the capital per worker where the EKC reaches the top level:

$$g_P = g_B + n - g_A < 0 \quad \text{or} \quad \alpha(\delta + n + g_B) - g_P > \alpha(\delta + n + g_B)$$

where the condition as for $k^{**} > k^*$,

$$g_P = g_B + n - g_A > 0 \quad \text{or} \quad \alpha(\delta + n + g_B) - g_P < \alpha(\delta + n + g_B)$$

then, condition as for $k^{**} < k^*$. These settings illustrate the model's growth patterns in terms of capital per effective worker.

In the upper panel of the Figure 2, the vertical axis represents the rates of change of (α times) capital per effective worker $\alpha \frac{\dot{k}_t}{k_t}$ and aggregate emissions g_P, whereas the horizontal axis represents capital per effective worker *k*. An assumption indicates in constructing the figure implicitly that growth is sustainable, such as $g_P <$ 0. The line with a negative slope defined by $\alpha s\,(1-\gamma)k_t^{\alpha-1}$ is referred to as the savings locus since it moves with the savings rate *s*. Beginning at positive infinity, the savings locus rapidly shrinks as the capital per effective worker (*k*) approaches infinite. Consequently, it intersects the two horizontal lines at points C and B, as indicated. It is evident from Equation (20) that the vertical distance between $\alpha s\,(1-\gamma)k_t^{\alpha-1}$ and the horizontal line with height, $\alpha(\delta + n + g_B)$ is only α times the growth rate of capital per effective worker. On the left side of B, capital per effective worker is rising, whereas capital per effective worker is declining on the right side of B. The steady-state capital per effective worker, k^*, can be found at the intersection at point B. When *k* is small, growth is quick, but it slows as *k* approaches k^*.

Due to g_P being constant, the growth rate of aggregate emissions receives most of the attributes of the growth rate of capital per worker, as shown by Equation (9). Thus, the vertical distance between the savings locus $\alpha s\,(1-\gamma)k_t^{\alpha-1}$ and the horizontal line with height, $\alpha(\,\delta+n+\,g_B)-\,g_P$ equals the percentage rate of change of emissions. This indicates that the emission growth rate is zero at C, positive on its left, and negative on its right. As indicated in the bottom panel of Figure 2, it is evident that point C can reflect a turning point in emission levels. Therefore, emissions peak at k^{**} and follow an EKC-type curve. Also, levels of emissions are increasing on the left side of C and decreasing on the right side of C. Under the premise that growth is sustainable, g_P is less than zero, and point C is to the left side of B, the model yields the EKC profile depicted in the lower panel (Brock and Taylor, 2010: 135-136).

Additionally, achieving a state of balanced growth means that when $\dot{k}$ is zero, output and capital are expanding at the rate of $n+\,g_B$. Nations that begin with low levels of capital grow quicker than their balanced growth path. For nations with low levels of beginning capital, gains in emission intensity are insufficient to offset the additional pollution generated by faster economic growth, resulting in higher total emissions ($g_{P,t}=\,g_{Y,t}-g_A>0$, for $k^{**}\,<\,k^{*}$). Economic growth ultimately slows sufficiently for developments in emissions intensity to surpass the more additional pollution produced throughout output creation, leading to declining in emissions ($g_{P,t}=\,g_{Y,t}-g_A<0$, for $k^{**}\,>\,k^{*}$). It also refers to constant growth and capital accumulation in abatement technology that can lead to an EKC, based on the parameters chosen.

Several features of the environmentally friendly Solow model are depicted in Figure 2 (Brock and Taylor, 2010: 137). If the model is accurate, point C will be to the left of point B, indicating sustained expansion. The time profile of emission levels is influenced by the initial capital stock, represented by *k(0)*, in relation to point C. If the economy starts with a low initial capital stock, emissions initially rise and then decline as development progresses, resulting in a hump-shaped EKC profile for emissions. However, if the initial capital stock is larger, emissions decline monotonically as the economy moves towards its sustainable growth path. The relationship between points C and B determines the peak emission time. The economy has found its sustainable growth path when the gap between points C and B is narrow and the parameter, g_P, is modest. Point C moves to the right of point B if growth is unsustainable, and emissions keep rising even when the economy achieves a balanced growth path if this is the case. Abatement is always occurring at the same intensity, and the ratio of emissions to output is decreasing at a consistent pace, denoted by, g_A, whether the system is in or out of a steady state (Brock and Taylor, 2010: 136).

Emissions can be predicted to increase, plateau, or decrease under the Green Solow model, with the growth rate of emissions decreasing monotonically in k. (Brock and Taylor, 2010: 136-137). Countries further away from point B have quicker emission growth than those closer to point B. No matter how bad things get, the rate of emission increase will eventually decrease down to the sustainable level shown above along the balanced growth path. The form of the emissions curve would indicate:

When the growth has sustainable progress, then $k^{**} > k(0)$, and the emissions growth rate is initially positive, but eventually becomes negative in finite time. The solution implies that $k^{**} < k^{*}$ condition will hold.

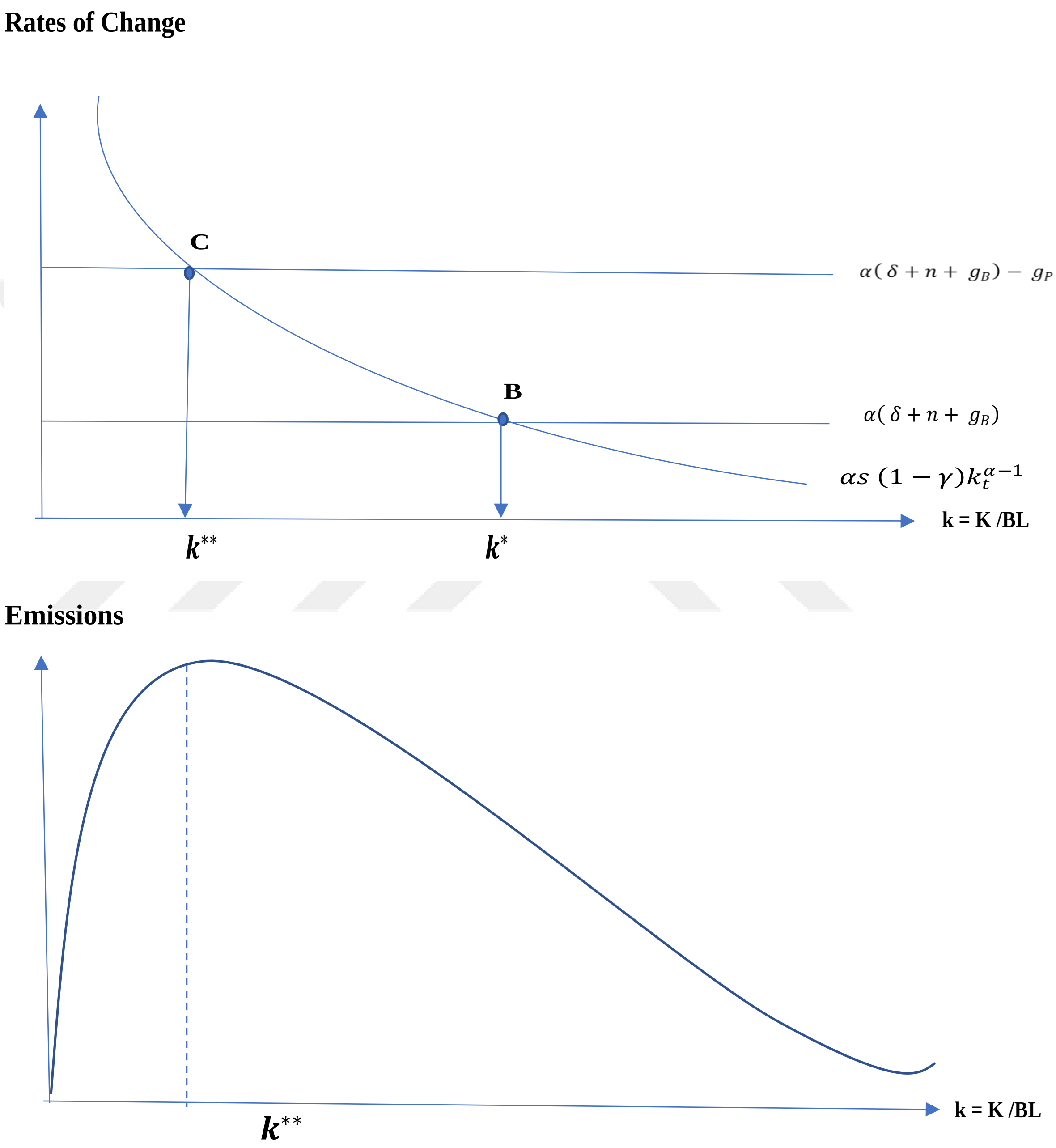
When the growth has sustainable progress, then $k^{**} < k(0)$, and the emissions growth is negative for all time. The solution implied that $k^{**} > k^{*}$ condition will hold.

The solution for k^{**} indicates it converges to k^{*} as time approaches to infinity. However, when the growth has unsustainable progress, then the emissions growth rate falls based on time but stays positive for all time.

The Green Solow model generates an EKC for income per capita and environmental quality. While the intensity of abatement is constant, there are no political, or economic conflicts to address. Despite its simplicity, it provides a highly plausible account for most of the empirical evidence between income levels and environmental quality. In Green Solow model, the determinants of the EKC are achieved by the accumulation of capital. However, this is shown by the dynamics of economic growth rates. Also, among other things, environmental capital is the basic capital that leads to the creation of other types of capital.

In conclusion, this section's model shows that sustainable development and environmental quality are linked to economic growth, technical advancement, and reduced pollution. The function of savings must be taken into account while analyzing the situation. Changes in the savings rate may alter short-term growth and the link between income and pollution in an economy, but they have no direct impact on the long-term growth rate of emissions or production. Figure 2 shows how a larger savings rate shifts the locus to the right, lifting C and B. Increased savings in both the steady state and at the turning moment raises capital per effective worker. It has been demonstrated that a rise in the savings rate extends the period until peak emissions (at point C). Therefore, a bigger peak in emissions occurs at a higher per capita income in economies with higher savings rates. The tipping threshold for emissions rises when the rate of capital accumulation increases due to increased savings (Brock and Taylor, 2010: 137). This means that the rate of increase in both output and emissions will be higher for a given value of *k*.

Figure 2: The Green Solow Model and the EKC



Source: Brock and Taylor (2010: 137).

The consequences of increasing the intensity of efforts to reduce pollution are noteworthy. Similar to changes in savings rates, alterations in abatement intensity do not have a long-run effect on economic growth as measured by output or emissions. Long-term aggregate emissions are totally governed by their growth rate, g_P, and their level, which is determined by initial conditions, k^*, and $a(\gamma)$. Changes in long-term growth rates of emissions are not affected by permanent policy changes that boost, (γ), which reduces emissions per unit of output by encouraging more efficient methods of production, and thereby reduces the economy's reliance on capital. The Green Solow model's assumptions mean that a stricter policy that raises (γ), cannot convert an unsustainable growth path into a sustainable one. This does not, however, rule out the possibility that policies might influence emission growth, economic development, and tipping points. The stricter the policy, the more it slows down the economy during the changeover (Brock and Taylor, 2010: 138). Considering why a rise in abatement decreases (1- γ) and shifts the savings locus to the left side, thus causing both C and B to fall.

Assume the influence of technological growth and changes. A rise in the rate of progress in abatement, g_A , causes a movement to the upper line in Figure 2, hence decreasing k^{**}. This decreases the emission growth rate for any value of *k*, as well as the growth rate in a steady state. Also, this modification has no influence on the production growth rate or on k^*. When combing these findings, it is clear that peak emissions occur at lower per capita income levels and occur earlier than expected.

The impacts of faster technological improvement in the production of goods are less distinct. A rise in g_B causes the top line in Figure 2 to shift downward, increasing at point C, and the bottom line to shift upward, decreasing at B. Also, the total emissions growth rate increases for all values of *k*, but the growth rate of capital per worker decreases for all values of *k*. The period to the top level of emissions could increase or decrease, and the peak per capita income could be higher or lower as a result.

Initial conditions, (s and γ) and (n, g_B and g_A) are three distinct drivers of factors that influence emission and income transition pathways, steady-state extents, and long-run growth rates (Brock and Taylor, 2010: 137). To a great extent, the shape of EKC is driven by declining GDP growth rates, which are linked with Solow's growth model convergence to a balanced growth path. The Green Solow model focuses on pollution accounting that theoretically gives explanations as a determinant of emissions. Each component of production, as well as technology and productivity, can be influenced by environmental regulations, thus affecting the GDP level of nations. Environmental protection policies may enhance natural capital. These policies might also have an implicit influence on the remaining two variables (capital and labor). For instance, cleaner air can boost labor supplies. The World Bank's "Inclusive Green Growth the Pathway to Sustainable Development" report from 2012 discussed the impacts of environmental policies on technology, which it referred to as the "input effect". Moreover, the concept of the "innovation effect" referred to the idea that environmental policies can promote innovation. Energy capacity measures may stimulate innovations that reduce both energy use and expenses, resulting in an increase in productivity. R&D expenditures done by the governments have the potential to boost private sector productivity. Investing in R&D analysis in the private sector also leads to technological advancements, as the government provides funding

Climate change policies benefit greatly from the usage of these models. A better understanding of growth theory helps us to explain the structure and consequences of these models. Because climate change is a negative externality, an environmental policy is required to implement the best in a market economy. In the absence of an environmental policy, the market simply considers marginal extraction costs and the costs of renewables. Consequently, there will be excessive usage of fossil fuels, and less will remain unextracted. In addition, in comparison to the previous growth models, the Green Solow model indicates an extension of the Solow model and understand climate change policies, green technology diffusion, and their reflections on sustainable development. Hence, in addition to its theoretical contributions, the Green Solow model is also a useful framework for making an estimation method to study the interactions between climate policies, environmental degradation, technological advancements, government policies, and economic performance.

2.4. CONCLUDING REMARKS

This chapter makes two significant contributions to the existing literature on green growth. Firstly, it expands the scope of the available literature review by examining various aspects of environmental technologies, climatic effects, and green growth. The review of the literature demonstrates that the factors underlying the enhancement of environmental-based growth and sustainable productivity are interconnected with global, economic, financial, political, social inclusion, environmental, and technological aspects by shedding light on the importance of environmental policies and strategies.

The chapter's second half examines the impact of two theoretical frameworks, the technology diffusion model and the Green Solow model, on economic growth and development. The primary goal is to improve environmental quality and foster sustainable development by decreasing carbon emissions, pollution, and waste. To better aid governments in creating and executing policies via shifting to a green economy, the theoretical framework seeks to enrich and expand current literature by investigating and addressing important knowledge gaps in green growth techniques and methodologies. To this end, green growth plans can help by providing a unifying framework for issues of economics, ecology, society, technology, and progress. It can also shed light on how governments might achieve economic growth while halting resource waste and environmental degradation. The spread of green technology across countries is crucial to the success of sustainable productivity.

Green growth strategies involve the rational management of environmental resources to prevent environmental problems and enhance economic growth and productivity. By implementing these strategies, it is possible to mitigate some of the environmental disasters that have been a concern for humanity since the 1970s. Green growth emphasizes energy efficiency, which can lead to significant energy savings and the creation of new employment opportunities by using labor-intensive sources of energy. These efforts can bring numerous benefits, such as the development of environmentally friendly products.

According to the UNEP report from 2011, the green growth model has the possible to result in higher economic performance in the long term compared to traditional models. A key finding of the report is that investing 2% of global GDP in natural capital, energy efficiency, and resource efficiency could lead to a long-term increase in GDP growth, although it may cause a temporary decrease in the short term (Ho and Wang, 2014: 7).

As mentioned in this chapter, the literature review suggests that developed and emerging countries, as well as nations with different economic and political conditions, face various challenges and opportunities in pursuing green growth. It also discusses on the various aspects of the green growth concept, including its definition, theoretical underpinnings, policy implications, and empirical evidence of its effectiveness. The literature review may also examine the challenges and opportunities associated with pursuing green growth, as well as the factors that influence its success. This could include factors such as policy and institutional frameworks, development levels, resource endowments, and specific environmental stressors. The literature review may also consider the experiences of different countries and regions in implementing green growth strategies and the lessons that can be learned from these experiences.

The green growth approach has been seen as a potential means of supporting economic recovery in the wake of economic crises or downturns. This is because green growth strategies can stimulate economic activity and create jobs in the green sector while also promoting sustainable development and enhancing natural capital. The environmental repercussions of economic activity may be mitigated, and economic stability can be strengthened, through green growth. However, there are also challenges to using the green growth approach in the context of economic recovery. To make the switch to a green economy, for example, large sums of money may need to be invested in new technologies and infrastructure, which can be difficult during economic downturns. In addition, some people may be resistant to green growth techniques since they require altering the status quo of economic institutions and behaviors.

In sum, the main conclusion reached in this chapter proposes a framework to evaluate the green growth approach in view of economic recovery, reduced carbon emissions, and environmental degradation by comprehending differences in sustainable development across countries. There are several potential outcomes when the Green Solow growth model includes multiple outputs and results (OECD, 2012: 9). These are summarized in Table 1.

The outcomes and results of the Green Solow growth model contribute to creating a more sustainable and equitable economy. Despite its disadvantages, the implementation of the green growth strategy is necessary both economically and ecologically, since the current economic system threatens the future of the world and the green growth strategy is a candidate to eliminate this threat. Moreover, this strategy is also necessary for preserving, sustaining, and restoring the natural environment to improve a democratic, accountable, and stable green economy. Through the broad framework that it offers, the Green Solow model appears as the best alternative to examine a substantial portion of the observed differences in the process of sustainable productivity.

Table 1: Summary of Outcomes of Green Solow Model

Economic results	Environmental results	Social results
Increasing GDP and distributing it more equitably through the traditional production	Increasing the efficiency of natural resource use and production	Improving livelihood opportunities, income, or quality of life, particularly for the poor
Enhancing the production of free ecosystem services or preventing their decline	Using natural capital within environmental limits	Providing useful employment for poor people
Promoting economic diversity to better manage economic risks	Enhancing other types of capital by using non-renewable natural capital in a sustainable manner	Promoting the development of social, human, and knowledge capital
Promoting the availability of renewable and green technologies to improve market security	Reducing negative environmental impacts and improving natural hazard and risk management	Reducing inequality

Source: OECD, (2012).

Despite the fact that these theoretical findings are instructive and consistent with an economic sense, their practical applicability is debatable. For instance, the development process of green technologies may or may not continue with sustainable productivity. At the same time, whether the impacts of climate change mitigation can result in sustainable components and environmental effectiveness or not is debated. Economic growth, investment, and new ideas may all be influenced by policies aimed at protecting the environment. It is often assumed that stricter environmental laws will have a chilling impact on investment and GDP development. However, this trade-off may be mitigated if new forms of creativity are encouraged. The green growth theory suggests that externalities, such as those related to environmental degradation, can be addressed through investment and innovation. In the following chapter, a thorough analysis will be conducted to investigate the factors that affect the spreading of green technology and the relationship between economic performance, climatic risks, globalization, and environmental-based growth. This empirical analysis helps to test the main predictions of the diffusion model and Green Solow model discussed earlier. As an added bonus, delving into the central debates surrounding green growth can shed light on the development of divergent views regarding economic incentives and processes, both of which have an influence on the development of the environmental approaches and the balance of power among its various sectors in the years to come.

The results presented in the following chapter provide positive support for the concept of green growth and environmental sustainability across various nations.

CHAPTER THREE
THE EMPIRICAL ANALYSIS

3.1. INTRODUCTION

Sustainable development and environmental protection are at the heart of the "green growth" economic strategy. This method acknowledges that progress in both economic development and environmental conservation need not be at odds with one another. A green growth strategy can be implemented through various policies and practices, such as increased use of essential elements, reduced reliance on fossil fuels, use of environmental-based technologies, and conservation efforts. The goal of the green growth approach is to create a more sustainable and inclusive economic model that benefits both the environment and society.

The theoretical foundation of the interplay between the environment and economic policy was the primary emphasis of the preceding chapter's literature survey. The term "green growth" has gained popularity as countries throughout the world strive to promote ecologically responsible economic growth and development. Green growth is seen as a way to tackle climatic effects, biodiversity loss, and natural resource depletion while simultaneously boosting the economy and creating new employment.

The Sustainable Development Goals of the United Nations and the Paris Climate Agreement are just two of the many worldwide programs and agreements that have incorporated green growth in recent years. These efforts and agreements have helped to elevate green growth and push countries toward environmentally and economically sound policies and practices.

Green growth is also supported by a variety of international organizations and agencies, including the World Bank and the United Nations Environment Programme. In addition to facilitating international collaboration and coordination on green growth concerns, these organizations aid nations in making the shift to more sustainable types of economic performance. Overall, environmental-based technologies and policies have become an important part of the international agenda and promoting sustainable development and addressing global environmental challenges. To do so, one way to promote green growth is to invest in renewable energy sources. Investing in clean technology can also reduce pollution and improve energy efficiency. Another way to promote green growth is to focus on sustainable land-use practices. These practices may include protecting natural habitats and biodiversity, as well as promoting sustainable agriculture and forestry practices. Protecting natural habitats preserve the ecosystems that support plant and animal life, while sustainable agriculture and forestry practices reduce the amount of land that is used for farming and logging.

This thesis also takes into account the global dissemination of environmentally friendly technology, which is one of the main topics discussed. These are a range of technologies, such as renewable energy sources, energy-efficient building materials, and low-emission transportation systems. Sustainable development and environmental protection are two goals that governments and non-profits from all around the world are working to achieve. To achieve environmental goals, many countries are promoting environmental technologies through various policies and initiatives. Likewise, the diffusion of green technology can also bring economic benefits, such as job creation and new business opportunities. As more and more people and organizations adopt green technology, the demand for these technologies will increase, leading to innovation and growth in the green technology sector. This can contribute to economic development and reduce dependence on fossil fuels. Therefore, the spread of green technology is a significant part of the international agenda as it helps us to address environmental degradation and promote a sustainable environment.

The global debate regarding the correlation between environmental concerns, climate change adaptation, and economic performance has persisted over an extended period. In order to meet the problems provided by global warming and restrict global warming to below 2 degrees Celsius compared to pre-industrial levels, the Paris Agreement was ratified in 2015. The agreement necessitates countries to curtail their CO2 emissions and adjust to the consequences of climatic risks. To address climate change adaptation, nations have formulated strategies and activity programs at the national level. These plans entail conducting assessments to determine the potential influences of climatic risks on a country and subsequently devising strategies to alleviate these effects.

However, the success or failure of green growth strategies depends on more than just these efforts. These include the unique traits and conditions of each nation or area, as well as a wide range of economic, social, and political issues. The economy is a critical factor in green development. Countries with robust and stable economies are better equipped to implement green growth strategies because they have the financial and institutional resources to facilitate the shift toward greener forms of economic growth (Baker, 2006: 31). Likewise crucial are political considerations. Green development plans are more likely to be effective when there is a favorable political climate and widespread public support for environmental conservation. Policies are more likely to be adopted and enforced effectively in nations where there is substantial political support for green growth.

Technological advances are also crucial. Important factors in determining green growth also include the accessibility and affordability of green technology and technical advances. Transitioning to a more sustainable form of economic exchange is easier and less expensive in nations with access to modern green technology. Finally, natural resources are also crucial to green growth's development. The effectiveness of environmental-based strategies can also be affected by the quantity and quality of available natural resources including land, water, and minerals. It may be less difficult to adopt green growth techniques in nations with an abundance of natural resources than in those with less resources. Numerous elements, some of which may vary by nation or location, contribute to the overall effectiveness of green growth initiatives.

In the framework of green growth strategies, this chapter presents two empirical research. Many questions remain unanswered in empirical green growth models about the causes and consequences of the green development process. To begin, green empirical models are a specific category of economic models that analyze the impact of environmental conditions on economic performance. These models assess the effect of environmental regulations on economic indicators like GDP and employment rates by utilizing data and statistical methods. By calculating how a carbon tax might influence consumer behavior and the economy as a whole, for instance, a green empirical model may be used to analyze the tax's economic consequences.

Secondly, green empirical models are used by policymakers to evaluate the trade-offs between economic performance and environmental protection. These models provide a quantitative analysis of the costs and benefits of various environmental policies, enabling policymakers to decide how to balance economic growth and sustainability. Empirical green models are a valuable resource for policymakers seeking to understand the impacts of different environmental policies and make choices that consider both economic and environmental considerations.

Lastly, green empirical models typically use a range of data sources, including economic data, environmental data, and data on the behavior of consumers and firms. The statistical methods used by these models to evaluate the connections between the environment and economic results may include regression analysis and time-series analysis, among others. It is possible that parts of behavioral economics will be included in certain green empirical models to better understand how individuals and businesses behave to shifts in environmental policies.

In a nutshell, "green growth" is an expansion of the economy that does not compromise efforts to preserve and improve the natural world. The goal of green growth research is to determine if and how economic development may be achieved without compromising environmental quality. Evaluating the effects of proposed policy changes on economic development and environmental quality is a common goal of such research. Economic results like GDP and employment, the significance of environmental-related technology, the possible consequences of carbon emissions, the trade-offs between economic growth and environmental conservation, and how to strike this balance are all elements that can influence green growth. Green growth promotion can also be affected by institutional and political issues. Green development can benefit from environmental regulations and climatic consequences and its effects. All of them must be taken into account for green growth promotion to be successful.

Overall, the main aim of this thesis is to provide a brief insight into the question of how economic performance and the variety of determinants affect green growth in selected countries. We will first explore the environmental, economic, social and political determinants of green technologies for a selected sample of countries. While some of potential factors have been studied in the context of sustainable development (Hötte, 2020; Kempf and Rossignol, 2007; Popp, 2006; Popp et al., 2010; Vona and

Patriarca, 2011; Du et al., 2019), their role as determinants of green technology diffusion has not been thoroughly explored. This thesis contributes greatly since it examines and ranks various possible causes of green development. The first goal of the study is to explore the connection between overall patterns of technology dissemination and individual technical advances, and the second is to investigate the variables that influence the spread of green technology. The study fills a gap in the literature and improves our knowledge of the factors that motivate the development of environmentally friendly technology and their effects on long-term ecological sustainability.

We then analyze the effect of these variables at the national level on the green growth index. Our analysis takes into account a wide range of potential determinants of the green growth index, including but not limited to: economic growth; the spread of environmentally-friendly technologies; the adaptation to climate effects; the globalization index; sustainable productivity, and political and environmental factors. The specific inclusion of environmental factors in the green growth model is relatively limited, though many of these have been studied in the context of environmental sustainability and the determinants of environmental-based approaches (Tawiah et al., 2021; Khan et al., 2020; Xu et al., 2021; Fernandes et al., 2021; Hussain et al., 2022). Our goal in include these variables is to enrich our understanding of the relationship between macroeconomic parameters and the green growth index, so making a significant contribution to the existing research. We investigate that by looking deeper into this connection and describing the determinants of environmental-based technology diffusion, we will be able to gain insights and information that will help us better comprehend the role those different economic elements play in the quest for environmentally-friendly growth.

The rest of the chapter is arranged as follows. Section two examines the broad range of macroeconomic determinants of green technology diffusion while the third section delves into the impact of various determinants, such as globalization, economic and political factors, climate and technological advancement, and environmental determinants, on the process of achieving green growth. Finally, section four summarizes the findings and concludes the chapter.

3.2. THE DETERMINANTS OF GREEN TECHNOLOGY DIFFUSION

Environmental variability and climatic conditions present significant challenges to sustainability. These challenges can be environmental degradation, pollution, climatic variability, local resource depletion and degradation, and human modification of the environment. Environmental modification is part of the economic development and growth process. In this process, green technologies make a contribution to regulating the environment and rationalizing and modernizing society and human use of nature. Green technologies embody a particular epistemology of development and understanding food, technology, nature, and culture. Moreover, they support research and development investments, decrease the cost of materials and production costs, and raise production rates.

Green technologies have both positive and negative dynamics in the green growth process. Governments, for instance, are gradually focusing on the improvement of eco-friendly technologies and employing tax measures that have a positive impact on green technologies. The implementation of taxes related to environmental issues typically results in the development of new technologies and methods that involve eco-friendly products and enhanced production procedures.

Recent academic and institutional policy discussions have highlighted the benefits of technological innovation and climate change mitigation (Jaffe et al., 2003: 5). Sustainable environment attempts to achieve environmental goals and reduce costs, as well as promote the production and spread of innovative eco-friendly technology. It's important to note that the market failures related to technology development are distinct from green externalities. As a result, the diffusion of new, practical, eco-friendly technologies is a subject of great importance in both research and policy due to the two-way externality involved.

Even while the development of green technology is crucial to sustainable development and climate change mitigation, all these improvements may not automatically lead to their widespread acceptance and realization of their benefits. The rate of adoption and use of new technologies is strongly influenced by the process of technology diffusion. It is through the diffusion process that the advantages of green technologies are recognized and embraced by individuals, organizations, and societies.

According to Allan et al. (2013: 5), the process of green technology diffusion is more vital for adaptation than its invention, and it reduces environmental externalities. They also examined the spreading of green technology in linkage to the diffusion of all technologies and analyzed the relevant economic theory. Their findings indicate that general trends of a technological spreading show in a nation as one of the determinants of the pace of the technology process. Moreover, environmental technologies may come up with environmental externalities reduction. According to a number of studies, the broad use of green technology will yield huge advantages (Hall, 2004: 10).

To better promote, accelerate, and assist technology adoption, Waisman et al. (2019: 21) constructed an approach that investigates the contexts, methods, and facilitation requirements of implementing green technologies. The strategy of identifying initiatives to accelerate and support the adoption of technology, along with strengthening policies and legal frameworks, is crucial for policymakers. Recognizing the challenges in mitigating the effects of climate change, it becomes evident that individual national efforts alone may have limited impact. Therefore, taking a global policy perspective becomes imperative. Coordinated global action is necessary to address the scale and complexity of climate change. By adopting a global perspective, policymakers can develop collaborative strategies, share best practices, and implement policies that have a far-reaching and collective impact.

In light of this context, this thesis will first investigate a wide variety of national-level macroeconomic indicators that may affect the spread of environmentally friendly technologies. For instance, income level, inequality, socioeconomic conditions, democratic societies, education level, and foreign direct investments are the major socio-economic and macroeconomic indicators showing the diffusion process (Torras and Boyce, 1998; Wang et al., 2020). There are also several environmental factors, such as carbon emissions and environmental conditions and performance at the country level. These factors will also be evaluated as important determinants of green technology diffusion.

The investigation into the determinants of environmental technologies makes several valuable contributions to the current literature. Firstly, we prioritize the diffusion of green technology over its creation, which distinguishes our research from previous studies. Secondly, we address a notable gap in the literature by examining the role of brown technology, encompassing a broader range of technologies, in driving green technology diffusion. This approach fills a substantial knowledge vacuum and provides a comprehensive understanding of the interplay between different technological domains and their impact on the spreading of environmental products and technologies. Thirdly, within the theoretical framework, our study contributes to the existing literature by examining the relationship between the determinants of green technology diffusion and not only environmental factors but also potential factors. These variables include democratic accountability, economic growth, socioeconomic conditions, FDI, and environmental enhancements. By considering these factors in our analysis of 58 selected countries, we capture a wide range of influences on green technology diffusion, including variables that have not been extensively studied before. Fourthly, we extend the duration of our analysis, encompassing a more extensive time span. This enables us to capture long-term trends and dynamics in the diffusion of green technology more comprehensively.

Additionally, we expand the scope of our study by including a greater number of nations. By incorporating a broader range of countries, we enhance the generalizability and applicability of our findings. Moreover, we address the issue of endogeneity that may have been overlooked in prior studies by utilizing panel data models. These models allow us to consider the potential reciprocal relationships and feedback mechanisms between explanatory factors and green technology diffusion. Furthermore, we employ dynamic panel data model that account for time-dependent effects and sluggish adjustment processes. This allows us to capture the gradual and delayed impacts of the determinants on green technology diffusion, offering a more nuanced understanding of the underlying dynamics.

The rest of this section is organized as follows. We will first introduce the data and describe the empirical model. Then we will report the empirical results of cross-sectional and panel data regressions. Lastly, the findings will be summarized and discussed in line with previous literature by proposing policy implications.

3.2.1. Data Description and Empirical Model

This section presents the data, the empirical model estimated, and the outputs of the analysis regarding the factors of green technology diffusion. Hence, this whole section is devoted to cross-country analysis based on various determinants. The dynamic panel data estimation has been used extensively in several empirical studies of the environment. To address potential issues such as autocorrelation issue, endogeneity and heteroskedasticity problems, researchers have turned to the Generalized Method of Moments (GMM) estimator developed by Arellano and Bover (1991) and Blundell and Bond (1998).

Furthermore, it is important to note that the ordinary least squares (OLS) method can be biased and inconsistent in the absence of unobserved national effects that remain constant over time. This is because OLS assumes that the error term is uncorrelated with the explanatory variables. However, in the presence of time-invariant unobserved factors at the national level, this assumption is violated, leading to biased and inconsistent estimates. To address this issue, we employ advanced panel data techniques that account for these dynamic effects and provide more accurate and reliable estimates. By considering the dynamics of the data and controlling for unobserved heterogeneity, we enhance the validity and robustness of our findings, ensuring more accurate inference regarding the determinants of green technology diffusion. We control the variance inflation factor, which is found to be greater than 10, identifying problematic levels of multicollinearity.

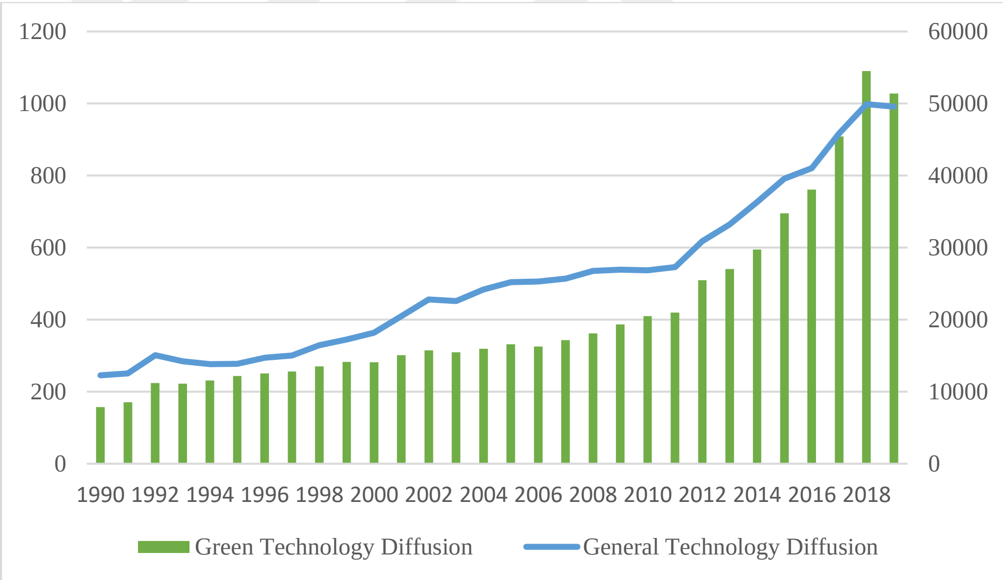
The study employs a yearly panel dataset from 1990 to 2019 for the 58 developed and developing countries because of the data availability, which is listed in Appendix 1. Additionally, this study examines the environmental technologies and also general technology spreading by utilizing data sourced from the World Intellectual Property Organization's (WIPO) patent database. The WIPO collection, which comprises indicators and statistics, is used to assess the influence of patents on environmental progress. This WIPO dataset enables governments to assess the innovation performance of their population and enterprises, as well as establish policies to protect the environment and foster technological development.

Figure 3 shows a worldwide average for the variables of green technology dissemination and general technology diffusion from 1990 to 2019. Between 1990 and

2010, both conventional and environmentally friendly technology spread steadily. Since 2010, however, the diffusion of ecologically friendly technology has accelerated. In addition, time series plots represent in Appendix 2 of countries by income groups from 1990 to 2019.

The World Development Indicators (WDI) database covers a wide range of indicators, including economic, social, demographic, and environmental variables. We collect per capita GDP estimates that are adjusted for purchasing power parity (PPP) and expressed in U.S. dollars, also carbon emissions per capita in metric tons from WDI. In addition, foreign direct investment is obtained from WDI, and foreign direct investment as a percentage of GDP is calculated as an indicator. We also take the income inequality dataset from the World Inequality Database (WID).

Figure 3: Green Technology Diffusion and General Technology Diffusion, 1990-2019



Source: Author’s own calculations.

The Political Risk Services (PRS) Group’s database is utilized in this study to gather data on democratic accountability and socioeconomic circumstances. The database provides indices that measure the level of democratic accountability and socioeconomic conditions in various countries. These indices are scaled from 1 to 10, where higher values indicate better performance. The environmental performance index used in this study is obtained from the Socioeconomic Data and Applications Center (SEDAC). This is a specialized data center that focuses on socioeconomic and environmental data. They provide a comprehensive dataset that includes various indicators related to environmental performance. The data cluster for the environmental performance index is based on 25 indicators[3] and 10 policy classifications[4] (Emerson, et al., 2010: 11-12). This dataset consists of the environmental impacts of disease, water, air pollution, climate change, water facilities, biodiversity, the natural environment, forestry, fisheries, and agriculture (Emerson et al., 2010: 13).

Lastly, technological developments are essential for sustainable development and economic prosperity. The Technology Achievement Index (TAI) rates the technological performance of nations and categorizes them based on their technological accomplishments. It seeks to enhance sustainability through nations' capacities and the use of environmental and technological outputs. The TAI uses a technique created by Desai et al. (2002). Improvement of human skill, new technology invention, diffusion of old technology and new technology are the four aspects and sub-indicators of the TAI (Nasir et al., 2011: 42). This study utilizes gross enrollment ratios at all levels of education, which measure the proportion of students enrolled in educational institutions at various levels, including primary, secondary, and tertiary education. To measure the growth of new technologies, patents, and royalties and licensing fees that are issued by inhabitants are collected (in US dollars per person). Older technology will spread thanks to the availability of electricity (kWh per person), telephone mainlines, and cellular users (per 1000 people). Similarly, the diffusion of new technologies is assessed using two indicators such as internet users per 1000 persons and high-tech exports. The average TAI for 58 nations is shown in Figure 4 for the period from 1990 to 2019. It has been demonstrated that there was a slowdown in the development of TAI after 2005, which eventually led to a nearly stagnant state

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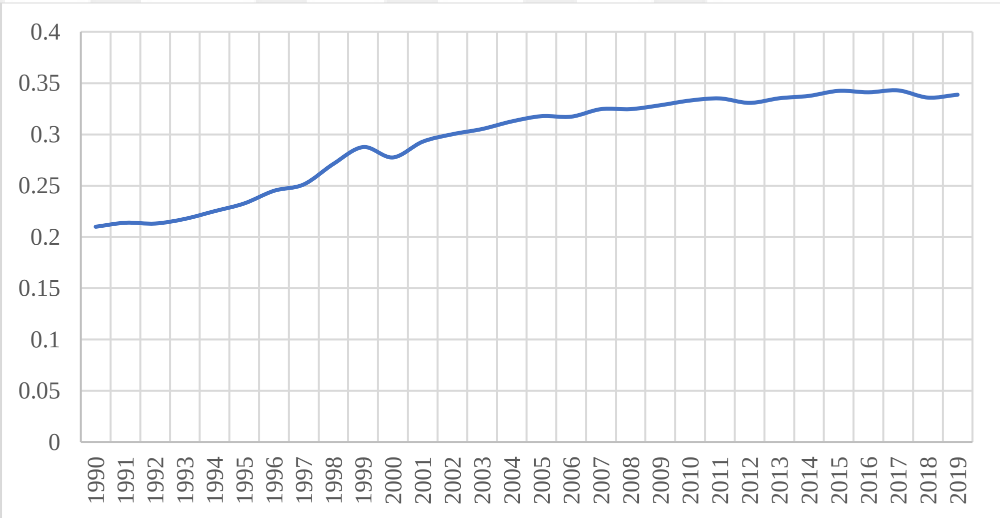
[3] EPI relies on 25 indicators that capture the Environmental Burden of Disease, Urban Particulates, Sulfur Dioxide, Nitrogen Oxides, Non- Methane Volatile Organic Compounds, Ozone Exceedance, Water Stress, Marine Protected Areas, Agriculture Water Intensity, Greenhouse Gas Emissions Per Capita, CO2 Emissions Per Electricity Generation and Industrial Greenhouse Gas Emissions Intensity.

[4] The ten policy categories are as follows: (1) Environmental Burden of Disease; (2) Water Resources for Human Health; (3) Air Quality for Human Health; (4) Air Quality for Ecosystems; (5) Water Resources for Ecosystems; (6) Biodiversity and Habitat; (7) Forestry; (8) Fisheries; (9) Agriculture; and (10) Climate Change.

by 2015. In addition, time series plots for the average technology achievement index of countries by income groups from 1990 to 2019 are provided in Appendix 2.

As for the empirical model, the previous studies explore the influences of potential factors on the creation and adaptation of technologies (Policardo, 2015; Zecca and Nicolli, 2021; Halkos and Skouloudis, 2021; Koubi et al., 2012). This study expands the investigation of the impact of technical advancement, environmental legislation, political variables, and economic growth on the dissemination of environmental technologies in a broad sample of global economies. Consequently, this study identifies the key drivers and barriers that shape the adoption and spread of environmental technologies.

Figure 4: Technology Achievement Index, 1990-2019



Source: Author's own calculations.

Within the scope of this thesis, there are two empirical studies which employ a panel data methodology. By utilizing a panel dataset, it is possible to attain degrees of freedom by extension of the time-series dimension's variability and, more crucially, by controlling for unobserved specific influences of countries. In addition, when the country-specific effects are linked with the lagged independent variables, a dynamic panel estimator can generate consistent and productive estimations. These models provide an overview of the GMM framework and convey currently some of the crucial problems in the process. Unlike OLS, which requires that the data meet certain assumptions, GMM can be used even when these assumptions are not satisfied. For instance, GMM can be used with data that is not normally distributed or with dependent data, such as data from a panel study. In GMM estimation, the model's parameters are estimated by choosing values that minimize the difference between the models predictions and the actual data (Roodman, 2009).

The model takes the general form,

$$Y_{i,t} = \beta_1 Y_{i,t-1} + \beta_2 X_{i,t} + \mu_{i,t} \tag{1}$$

$$\mu_{i,t} = \eta_i + \varepsilon_{i,t} \tag{2}$$

The extended form of equation (1):

$$Y_{i,t} = \beta_1 Y_{i,t-1} + \beta_2 X_{i,t} + \eta_i + \varepsilon_{i,t} \tag{3}$$

where *i* and *t* show countries and time periods respectively, the unobserved influence of country *i* is denoted by η_i , and the observed-specific errors of country *i* at time period *t* is denoted by $\varepsilon_{i,t}$. Moreover, $Y_{i,t}$ is the dependent variable and $X_{i,t}$ is the independent variables.

The OLS estimator may produce biased coefficient estimates due to the existence of a lagged dependent variable as an explanatory variable in equations (1) and (3). The reason for this is that the lag variable could be related to other explanatory factors. Since Maximum Likelihood (MLR)'s assumption should be scrupulously adhered to, this is a violation. To this purpose, Hsiao (1986) demonstrates that in the presence of individual-specific effects, OLS estimates of the autoregressive parameter would be biased higher. Because there is an unobserved cross-country effect, there are lagged dependent variables, and there is a problem with endogeneity, we use the GMM estimating method to fix these problems.

The rest of this subsection presents results based on three models. Firstly, these models present a GMM estimate for the concerning parameters. Using the terminology established in equation (3) the models are extended to the formal panel data framework. One step more can be rewritten as the following expressions:

$$Y_{i,t} = \beta_0 + \beta_1 Y_{i,t-1} + \beta_2 X_{1i,t} + \beta_3 X_{2i,t} + \beta_4 X_{3i,t} + \eta_i + \varepsilon_{i,t} \tag{4}$$

where $X_{1i,t}$, $X_{2i,t}$, $X_{3i,t}$ represent the explanatory variables, resulting in biased coefficient estimates if OLS is used as an estimation technique. Some of the main regressors are endogenous, which means $E = (X_{1i,t}\mu_{i,t}) \neq 0$. Thus, the T_1 regressors when $X_{1i,t}$ variable is endogenous, the remaining variable are assumed to be exogenous.

It is important to note that the validity of the instruments used in a two-step System-GMM estimation model is essential for obtaining consistent and productive estimators using this method as opposed to static models. This estimator has been shown to have high finite sample biases, as discovered by Newey and Smith (2004). It is often considered the most effective option for System-GMM estimation models because it uses a consistent estimate of the moment conditions' covariance matrix for weighting, whereas this estimator uses weight matrices of independently estimated parameters (Windmeijer, 2006).

Previously, the determinants of environmental technologies have investigated in several studies. The primary factor that contributes to the development of green technology diffusion and sustainable development is the income level of countries. Fatima et al. (2021: 1227) have found that the proportion of renewable energy consumption to CO2 emission decreases as income increases, while other studies (Khan et al., 2020; Zecca and Nicolli, 2021; Bilal et al., 2022) have shown that higher GDP leads to an increase in carbon emissions. The second crucial factors for adopting green innovations are investment and trade. Khan et al. (2020) have provided evidence of a robust causal relationship between export and import levels, GDP growth, technology creation, and changes in consumption-based CO2 emissions specifically in G7 countries. The findings suggest that policies related to trade, such as promoting green exports and imposing environmental standards on imports, can contribute to reducing carbon emissions.

Green technologies have also been studied through economic development, socioeconomic conditions, democratic accountability, technology innovation, and environmental performance. According to Wang et al. (2020), political freedom and institutional quality aid to lower CO2 emissions while financial development and economic growth exacerbate environmental deterioration. The outcome is consistent with the findings of Wejnert (2020) and Söderholm (2020). Furthermore, according to the study by Zuhair and Kurian (2016: 130), there are several social and economic obstacles that hinder the spread of eco-friendly products. These include gender disparity, insufficient resources, and funding, a diminishing sense of community, and inadequate environmental awareness. Chaudhry et al. (2021: 314) discovered that in more affluent East-Asian and Pacific countries, there is a notable favorable connection between environmental indicators and advancements in technology. Our findings, which encompass a wide range of countries including both developing and developed nations, provide a valuable addition to the existing findings in previous studies. By including a diverse set of countries in our analysis, we are able to offer a more comprehensive and robust understanding of the relationship between the variables under investigation. This coverage allows for valuable insights into the role of different economic and policy factors in shaping environmental sustainability across a diverse set of countries.

Our analysis investigates whether the factors influencing the spread of green technology have a beneficial impact on achieving a sustainable environment, which corresponds with existing literature. Using the System-GMM estimator in the analysis is designed for "small *T*, large *N*" panels, where there are few time periods and many individuals (Jung et al., 2015: 58).

Following is the overall form of the model that will be used in the study:

$$gtd_{i,t} = f(da_{i,t}, fdi_{i,t}, soc_{i,t}, ineq_{i,t}, td_{i,t,}, epi_{i,t}, gdp_{i,t}, tai_{i,t}) + \varepsilon_{i,t} \tag{1}$$

where *gtd* expresses green technology diffusion. The independent variables are foreign direct investment (*fdi*), income inequality (*ineq*), general technology diffusion (*td*), democratic accountability (*da*), socioeconomic conditions (*soc*), environmental performance index (*epi*), per capita GDP (*gdp*), and technology achievement index (*tai*). Natural logarithms are used for all variables. $t = 1, 2, ..., T$ represents time, whereas $i = 1, 2, ..., N$ means countries in the equation. The specific form of the model is expressed as follows:

$$\ln(gtd_{i,t}) = \alpha_0 + \sum_{j=1}^{q} q_i \ln(gtd_{i,t-j}) + \beta_1 \ln(da_{i,t}) + \beta_2 \ln(fdi_{i,t}) + \beta_3 \ln(soc_{i,t}) + \beta_4 \ln(ineq) + \beta_5 \ln(td_{i,t}) + \beta_6 \ln(epi_{i,t}) + \beta_7 \ln(gdp_{i,t}) + \beta_8 \ln(tai_{i,t}) + \eta_i + v_{i,t} \quad (2)$$

$$\varepsilon_{i,t} = \eta_i + v_{i,t}$$

$$E(\eta_i) = 0, E(v_{i,t}) = E(\upsilon_{i,t}\eta_i) = 0$$

In natural logarithm form, the error term $\varepsilon_{i,t}$ in the autocorrelation order q equation consists of two orthogonal components, namely fixed effects η_i and idiosyncratic shocks $v_{i,t}$.

There are two main challenges when using the GMM technique: the need for more instruments and the serial correlation of error terms, according to Roodman (2009). These challenges are particularly pronounced when dealing with a panel dataset that has a few numbers of individuals and a great time period. Increasing the number of instruments means using more advanced instruments. The model becomes overidentified by creating instrumental variables in levels and differences. The Sargan and Hansen tests provide an opportunity to determine whether the sample size is sufficient and if the number of instruments used may lead to overidentification (Sargan, 1958).

In this study, the Arellano-Bond system GMM model is employed, and all variables in the regression are lagged up to the first and second order. This lagging approach allows for capturing the potential dynamics and time dependencies in the variables. Instead of adding an instrument per variable, lag interval, and time period, adding one instrument per variable and lag interval guarantees that all crucial variables are represented as instruments without introducing bias to our parameters (Arellano and Bover, 1995: 30).

A Sargan-Hansen J-test of over-identifying restrictions is a statistical test used to evaluate the validity of the instruments employed in a regression model. This test helps determine whether the instruments used in the analysis are valid and exogenous and not correlated with the error term and whether the model is correctly specified.

The two-step GMM estimator utilizes instrumental variables to account for endogeneity by first estimating the equation using moment conditions based on the instruments and then using the estimated residuals to construct a set of moment conditions for the second step. By incorporating the lagged endogenous variable as an instrument, the two-step GMM estimator allows for consistent and efficient estimation of the model while addressing the endogeneity problem (Roodman, 2009). As a result, this estimator is used to examine the empirical connections between specific variables and the diffusion of eco-friendly technologies (Arellano and Bover (1995); Blundell and Bond (1998)).

Furthermore, due to the substantial association between the variables of the green technology diffusion, technology achievement index, environment performance index, economic growth (see, for example, Table 4), we cannot able to investigate the whole model the whole model in a single equation, as shown in Equation (2). When deciding which variables to leave out of the model, one should take into account whether they are components of any remaining index variables, whether they measure the same idea as another factor in the model, or whether their strong correlation creates a severe multicollinearity issue. Therefore, as seen in Table 2, Model 1 is our base model, and we carefully added control variables to Models 2-5. Model specifications, all exclusion restrictions, and variables for the models are listed in Table 2:

Table 2: Model Specifications

Models	Exclusion constraint	Excluded indicators	Indicated association
Model 1:	$\beta_5 = \beta_6 = \beta_7 = \beta_8 = 0$	*td, epi, gdp, tai*	*gtd=f (da, fdi, soc, ineq)* + ε
Model 2:	$\beta_6 = \beta_7 = \beta_8 = 0$	*epi, gdp, tai*	*gtd=f (da, fdi, soc, ineq, td)* + ε
Model 3:	$\beta_7 = \beta_8 = 0$	*gdp, tai*	*gtd=f (da, fdi, soc, ineq, td, epi)* + ε
Model 4:	$\beta_8 = 0$	*tai*	*gtd=f (da, fdi, soc, ineq, td, epi, gdp)* + ε
Model 5:	$\beta_5 = 0$	*td*	*gtd=f (da, fdi, soc, ineq, epi, gdp, tai)* + ε

The description statistics for all of the variables is summarized in Table 3. These include the mean, standard deviation, minimum, and maximum values of each variable. The total number of observations is represented by (*n*) which has 1,740 individual data. Table 3 displays the descriptive statistics for the logarithmic levels of the variables. The first column of the panel lists the variable names for the logarithmic levels.

Table 3: Descriptive Statistics

Variables	*n*	Mean	Std. dev.	Min.	Max.
	Log levels				
lgtd	1,740	3.399	2.229	0.	10.696
ltd	1,740	7.203	2.585	0.	14.169
lepi	1,740	4.063	0.203	3.370	4.507
lgdp	1,740	9.777	0.816	6.890	11.703
ltai	1,740	-1.318	0.472	-3.863	-0.199
lineq	1,740	-2.081	0.383	-3.310	-0.973
lda	1,740	1.416	0.664	-3.178	1.792
lsoc	1,740	1.762	0.652	-1.792	2.398
lfdi	1,740	0.926	2.449	-6.446	24.053

Table 4 displays the estimated Pearson correlation matrix across all parameters. Multicollinearity in a model may be better understood by calculating correlation estimates to see whether there is a significant correlation between the variables in the model (Sarafidis et.al., 2009). It is revealed that the correlation coefficients between green technology diffusion and income inequality are all negative. Green technology diffusion is positively associated with several other characteristics. In addition, there is a strong positive correlation between several pairs of variables. Some examples of such combinations include green technology diffusion and general technology diffusion, GDP and technology achievement index, environmental performance index and GDP.

Table 4: Correlation Matrix

Variable	lgtd	lda	lfdi	lsoc	lineq	lepi	lgdp	ltd	ltai
lgtd	1.00								
lda	**0.28**	1.00							
lfdi	**0.39**	**-0.09**	1.00						
lsoc	**0.37**	**0.67**	**0.11**	1.00					
lineq	**-0.16**	-0.02	**0.10**	**0.10**	1.00				
lepi	**0.30**	**0.32**	**-0.18**	**0.32**	**-0.28**	1.00			
lgdp	**0.44**	**0.33**	**-0.12**	**0.53**	**-0.21**	**0.69**	1.00		
ltd	**0.96**	**0.34**	**0.37**	**0.44**	**-0.16**	**0.32**	**0.51**	1.00	
ltai	**0.59**	**0.31**	**0.12**	**0.32**	**-0.34**	**0.52**	**0.70**	**0.64**	1.00

Note: The boldface denotes to 1% significance level.

3.2.2. Empirical Results

Empirical analysis has commenced by conducting essential initial tests, including tests for cross-sectional dependence, homogeneity, and unit roots. It is crucial to consider cross-sectional dependency when investigating the relationships among variables in panel data models (Pesaran, 2021). Cross-sectional dependence refers to the possibility that the observations in different cross-sectional units may be correlated with each other, which could lead to biased estimation results if not properly accounted for in the analysis (Pesaran, 2008). Therefore, this issue has been carefully examined to ensure the validity and reliability of the results obtained from the panel data model.

Due to the possibility of nations being interdependent through various economic linkages and the influence of common causes, disregarding spillover effects might lead to inaccurate inferences and misspecification difficulties. To investigate Cross-Sectional Dependence test (CSD), we use three tests for: Breusch and Pagan (1980) LM test, Pesaran (2004) Scaled LM test, and Pesaran (2004) CD test. We also investigate the slope homogeneity by using two different tests: Pesaran and Yamagata (2008) standardized version of the Swamy (1970) homogeneity test (delta tests). The small sample properties of the $\tilde{\Delta}_{adj}$ test can be improved by using the following mean and variance bias adjusted version of ($\tilde{\Delta}$). Each model's dependent variable is green technology diffusion. Each of Models 1 through 5 includes the dependent variable, democracy, FDI, socioeconomic values, and income inequality, as well as one of the independent variables, technology achievement index, environmental performance index, GDP, general technology diffusion, and in the order specified. Model 5 is an extension of Model 1 and includes all four independent variables in addition to the original one.

Table 5 indicates the findings of tests conducted to assess cross-sectional dependency. The null hypothesis of no cross-sectional dependence is rejected in Model 1-5. These findings highlight the presence of cross-sectional dependency in the data, indicating interconnections or shared factors among the nations. Moreover, the results of the cross-sectional dependence tests guide the selection of appropriate unit root tests, which is a critical consideration. Given the cross-sectional dependency of the data, it is necessary to employ second-generation unit root tests, such as those proposed by Westerlund and Hosseinkouchack (2016) to ensure accurate and precise estimation.

Table 5: Cross-sectional Dependence Test

CSD Tests	Statistic	*p*-value	Statistic	*p*-value
	Model 1		***Model 4***	
LM	2052.342***	0.000	1905.264***	0.000
CD_{LM}	8.001***	0.000	6.057***	0.000
CD	19.145***	0.000	1.955*	0.081
Homogeneity tests				
$\tilde{\Delta}$	1.589	0.178	1.612	0.181
$\tilde{\Delta}_{adj}$	1.674	0.126	1.118	0.102
	Model 2		***Model 5***	
LM	2201.471***	0.000	2099.681***	0.000
CD_{LM}	6.245***	0.000	6.552***	0.000
CD	20.921***	0.000	9.225***	0.000
Homogeneity tests				
$\tilde{\Delta}$	1.086	0.277	0.987	0.421
$\tilde{\Delta}_{adj}$	1.291	0.197	1.055	0.188
	Model 3			
LM	2147.403***	0.000		
CD_{LM}	6.663***	0.000		
CD	21.556***	0.000		
Homogeneity tests				
$\tilde{\Delta}$	1.199	0.374		
$\tilde{\Delta}_{adj}$	1.410	0.254		

Note: The symbols **, and * refer to the 1% and 5% significance levels.

Slope homogeneity test outcomes are also included in Table 5. These statistical analyses fail to reject the null hypothesis of slope homogeneity across nations at any of the assumed significance levels. Therefore, it is improbable that the slope would differ between countries, and it indicates that the impact of independent factors on the spread of green technologies is consistent among 58 nations.

In this study, to evaluate the stationarity of the time series data with a cross-sectional dimension, second-generation unit root tests are utilized. These tests account for the cross-sectional dependency present in the data and provide more accurate results (Westerlund and Larsson, 2018). The outcomes of the unit root analysis, we use two specific tests employed: Pesaran (2007) Cross-section Augmented Im-Pesaran-Shin (CIPS) test and Pesaran (2003) Cross-sectional Augmented Dickey-Fuller (CADF) test are represented in Table 6. The findings indicate that all of the tests reject the null hypothesis of a unit root, at both constant and constant plus trend specifications, with a significance level of 1%. Therefore, the results of the CIPS and CADF tests indicate that all the variables are stationary, hence the two-step system GMM may be used for estimation.

Table 6: Panel Unit Root Tests

	Constant		*Constant and Trend*	
Variables	CIPS	CADF	CIPS	CADF
lgtd	-3.242**	1.214**	-3.754**	-3.739**
lda	-2.678**	-2.013**	-3.189**	-4.557**
lfdi	-3.357**	-3.147**	-3.696**	-3.144**
lsoc	-3.064**	-3.241**	-3.359**	-3.118**
lineq	-2.536**	-1.457*	-3.096**	-2.183**
lepi	-2.604**	-3.075**	-2.939**	-1.044**
lgdp	-2.243**	-5.245*	-2.754**	-5.454*
ltd	-2.612**	-4.875*	-3.012**	-4.286*
ltai	-2.327**	-3.478**	-2.763**	-2.804**

Note: The symbols **, and * represent to the 1% and 5% significance levels.

The two-step system GMM is a statistical estimation technique that is often used in econometric analysis. It is a variant of the GMM method, which is a flexible and powerful tool for estimating structural parameters in economic models. The two-step system GMM involves estimating the structural parameters of the model in two steps. In the first step, the model is estimated using a GMM estimator, which allows for the inclusion of various moment conditions. In the second step, the estimates obtained in the first step are used to construct. This two-step process can enhance the efficiency and robustness of the estimates.

Additionally, to account for potential autocorrelation in the error terms, autocorrelation tests are conducted. These tests examine whether the inclusion of sufficient lagged terms in the model adequately captures the autocorrelation present in the data. The GMM approach tests the validity and reliability of the instrumental variables and accounts for potential autocorrelation in the estimation process, enhancing the robustness and reliable of the results.

The GMM approach is chosen as the preferred estimation method in this study for several reasons. Firstly, all the series under investigation are stationary, meaning they do not exhibit trends or systematic changes over time. This characteristic makes the GMM approach suitable for the analysis. Secondly, there are potential issues of endogeneity, multicollinearity, and autocorrelation in the data. Multicollinearity refers to high correlation among the independent variables, which can lead to unstable and unreliable parameter estimates. Secondly, we use the dataset has a large cross-sectional dimension (N = 58 countries) and a fixed time dimension (T = 30 years). In such cases, the system GMM estimator, as described by Baltagi et al. (2012), is well-suited. The GMM estimator is specifically designed for stationarity with a large cross-sectional dimension and a short time dimension.

In this study, the dependent variable, green technology diffusion, is primarily influenced by general technology diffusion. However, it is important to consider that several indicators such as income level, technological accomplishment, environmental performance, and FDI, democracy may themselves be affected by the diffusion of green technology. This introduces endogeneity concerns and necessitates the use of appropriate estimation methods. Given the specific characteristics of the dataset and the endogeneity concerns, the GMM estimator is a suitable choice. The GMM estimator is able to address cross-sectional dependence and maintain consistency, as defined by Sarafidis (2009) and Sarafidis and Wansbeek (2012). By employing a subset of parameters based on exogenous instruments, a consistent GMM estimator can be obtained. We also ensure the robustness of our findings by conducting CD(ρ) tests to detect any potential error cross-section dependence in the system GMM estimates.

The empirical results of the GMM estimation as seen in Table 7, which includes one lag, should indicate the rejection of first-order serial correlation through the use of the Arellano-Bond test, rather than the rejection of second-order serial correlation. The results of these tests which suggest that the inclusion of the AR(1) lagged term is appropriate in the specification. Thus, whole models are evaluated with one lag of green technology diffusion. However, Models 1-5 conclude that AR(2) tests are significant at the 10% and 5% levels. To address this, an estimation of the models with two lags is performed, and the results show that both the AR(2) and AR(3) tests are not significant, indicating the rejection of the AR(2) specification. Table 7 also presents the validity of over-identification restrictions in the instrumental variables used in the GMM estimation. The results of the Sargan-Hansen J-test suggest that there is no evidence to reject the null hypothesis that the over-identification restrictions in the models are valid. This indicates that the instrumental variables used in the analysis are appropriate and satisfy the necessary conditions for instrument validity. Moreover, the findings of the CD(ρ) test provide evidence that there is error cross-section dependence. Detecting error cross-section dependence is important as it helps to assess the reliability and validity of the estimation results.

Our model examines possible predictors of green technology diffusion due to the overfitting and multicollinearity issues with five unique model specifications. Table 7 provides a concise overview of the estimations. The empirical findings show that the coefficient of democratic accountability variable is positive and statistically significant at the 10%, 5%, and 1% levels of significance for all model specifications. Therefore, the adoption of green technology is facilitated in more democratic settings, which is consistent with the findings of Zecca and Nicolli (2021). Moreover, the FDI is a significant contributor in all other models. The positive effect that FDI has on the growth of green technologies lends credence to the research of Halkos and Skouloudis (2021). FDI contributes to the transfer of technology, knowledge, and managerial skills to the host country, which can contribute to the development and diffusion of green technologies.

Table 7 shows that the variable representing socioeconomic circumstances has a significant and positive association in all model specifications. According to empirical evidence, nations with better socioeconomic conditions are more likely to spread environmentally friendly technologies; however, in order to better understand the spread of environmentally friendly technologies, income inequality must also be considered.

In this study, inequality is measured using the 10 % percent of family income share. The inequality variable has an adverse effect on all model specifications. The results are congruent with those found by Vona and Patriarca (2011). Therefore, the results show that rising income inequality hinders the spread of green technology whereas a fair income distribution encourages green innovation in communities. This is because limited access to finance, education, training, political will, and market demand can lead to hindering green technology diffusion. For instance, as economic inequality rises, the number of people and businesses that can afford to invest in green technologies decreases. This lack of financial resources can limit the spread and development of green technology. However, as economic inequality rises, access to quality education and training opportunities becomes limited, hindering the development and spread of green technology. On the other hand, economic inequality can create a concentration of power and influence in the hands of a few individuals or corporations. This concentration of power can lead to limited political will to invest in green technologies and create policies that promote their adoption and development. Lastly, as economic inequality rises, the purchasing power of the middle and lower-income groups decreases, limiting the market demand for green technologies.

The general technology diffusion variable is included in Models 2—5. In all model configurations, the estimates for the average coefficient of technology diffusion are positive and significant levels. Consequently, our empirical findings sustain the widespread adoption of environmentally friendly technologies is strongly linked to the overall diffusion of technology.

The environmental performance index (EPI) is included in Models 3—5. We observe EPI has a significant contributor and positively association with green technology diffusion. Thus, the finding reveals that in countries with good environmental performance, the proliferation of green technology is likewise robust, suggesting that giving environmental concerns a higher priority leads to the quicker adaption of green technologies. This is likely because the adoption and use of green technologies can reduce harmful environmental impacts and promote sustainable development.

In Models 4 and 5, the income level variable is included as one of the explanatory variables. Due to its overfitting and high correlation with GDP per capita, green technology diffusion, environmental performance index, and general technology diffusion, have positive but insignificant estimated coefficients in Model 4. On the other hand, GDP per capita is positive and statistically significant in comprehensive Model 5. Green technology, innovations, and patent applications are all expected to increase in countries with higher per capita incomes. Thus, a higher per capita income may indicate greater financial resources available for investment in green technology and a higher demand for environmentally friendly products.

Finally, the technology achievement index (TAI) is included in Model 5. However, we exclude general technology diffusion from the model due to avoid overfitting and multicollinearity with the technology achievement index. Spreading of general technology and technology achievement index overlap semantically. However, their data sets and calculation methods are different from each other. General technological diffusion is also highly correlated with income level and environmental performance index. In Table 7, empirical findings show that the technology achievement index increases the spread of green technologies and that this impact is statistically significant. Countries with a higher TAI rate have a faster uptake of green technologies. For this reason, environmental problems in these nations tend to be solved quickly, and environmental damage is kept to a minimum.

Overall, the ability of a country to adopt green technologies and embrace sustainable practices is influenced by a variety of factors, including its income level, investment profile, social and economic circumstances, democracy level, and environmental performance.

According to the findings presented in Table 7, most of the determinants examined in the study have a significant positive impact on the spread of green technologies, with the exception of inequality. The coefficient for the inequality variable is negative and statistically significant, indicating that higher levels of income inequality are associated with a lower diffusion of environmentally friendly technology. This suggests that addressing wealth inequality may be crucial in promoting the widespread adoption of green technologies. On the other hand, the study concludes that the spreading of green technologies is positively associated with technological achievements and environmental performance. This suggests that countries with higher technological advancements and better environmental performance tend to have a higher diffusion of green technologies. These findings support the idea that promoting technological innovation and environmental sustainability can contribute to the widespread adoption of green technologies. In summary, except for income inequality, all indicators have significant contributor to spreading of green technologies. These findings highlight the importance of paying attention to income inequality and promoting technological advancement and all attempts to environmental technologies.

Table 7: Dynamic Panel Estimations (system-GMM) for Various Model Specifications of Green Technology Diffusion

Variable	Model 1	Model 2	Model 3	Model 4	Model 5
l..lgtd	0.557***	0.240***	0.2431***	0.2461***	0.5325***
	(0.018)	(0.014)	(0.016)	(0.018)	(0.016)
lda	0.135***	0.0452***	0.0229***	0.0341***	0.0683***
	(0.022)	(0.011)	(0.0153)	(0.014)	(0.024)
lfdi	0.0177***	0.0051***	0.0083***	0.0070***	0.0139**
	(0.003)	(0.001)	(0.002)	(0.002)	(0.003)
lsoc	0.249***	0.0497***	0.0491***	0.0349***	0.0954*
	(0.025)	(0.018)	(0.012)	(0.012)	(0.011)
lineq	-0.0646***	-0.2261***	-0.2214***	-0.221***	-0.2225***
	(0.085)	(0.005)	(0.029)	(0.039)	(0.023)
lepi			0.2464***	0.1921***	0.6634***
			(0.040)	(0.043)	(0.035)
lgdp				0.0331	0.602***
				(0.027)	(0.037)
ltd		0.5645**	0.5573**	0.5503***	
		(0.005)	(0.003)	(0.012)	
ltai					0.4579***
					(0.037)
Constant	0.7822***	-2.0816***	-2.9908***	-3.014***	-4.628***
	(0.081)	(0.117)	(0.187)	(0.309)	(0.236)
N	1682	1682	1682	1682	1682
$\hat{\sigma}^2$	0.279	0.161	0.068	0.181	0.165
χ^2	3909.432***	4007.49***	4325.612***	2612.001***	2449.990***
AR(1)	-4.553***	-4.3927***	-4.570***	-4.430***	-4.490***
AR(2)	2.3808**	1.876**	2.378*	1.9102*	1.9548*
Sargan *J* stat.	56.988	50.8572	57.431	49.0864	53.4197
CD(ρ)	1.781	1.045	0.501	1.002	1.388

Note: *, **, and *** indicate statistically significant at 10%, 5%, and 1% levels. Standard errors represented in parentheses.

3.2.3. Concluding Remarks

This section of the study aims to identify the determinants of environmentally friendly technology diffusion by examining a range of economic, social, political, and environmental factors. The dataset used spans from 1990 to 2019 with annual frequency. The empirical analysis reveals significant and positive associations between the dissemination of green technologies and various factors, including economic and environmental performance, FDI, socioeconomic values, the level of democracy in society, technological change, and technological achievements. These findings represent the significance of these factors in driving the adoption and dissemination of green technologies in the selected countries.

One of the potentially important factors that promote the adoption and diffusion of green technologies is the income level of countries. As maintained by Fatima et al. (2021), countries have higher income levels tend to be associated with greater adoption of green products and activities. and sustainable development. Higher-income levels provide countries with greater resources to invest in development of green technologies. This can include funding for scientific research, development of new technologies, and investment in renewable energy infrastructure. Such investments are costly, and higher income levels can enable countries to bear the associated costs more easily. Also, income levels can be associated with greater public awareness and concern for environmental issues. This creates a demand for green technologies, which can in turn incentivize companies and innovators to develop and market these technologies more widely. Lastly, income levels can be associated with more advanced institutional and regulatory frameworks that support the spread of green technologies. This includes renewable energy production, tax incentives for green investments, and regulations that incentivize businesses to adopt sustainable practices.

Moreover, our findings indicate a negative relationship between inequality and the spread of environmentally friendly technologies in all model specifications. This finding concludes that as inequality in a country increase, it tends to adopt and diffuse green technologies at a slower pace. Our finding aligns with the findings of Kempf and Rossignol (2007) and You et al. (2020). There are several reasons that inequality can negatively impact the diffusion of green technologies. Inequality leads to unequal access to information and knowledge about green technologies, which can impede their adoption and diffusion. For instance, households or businesses with limited access to information about the benefits of green technologies may be less likely to invest in them. The presence of inequality poses political obstacles that can hinder the widespread adoption and dissemination of green technologies. Furthermore, inequality leads to limited research and development on green technologies, particularly in low-income countries where there may be limited resources for innovation. Lastly, inequality results in limited access to financing for green technology adoption, particularly for low-income households or small businesses. This can impede their ability to invest in green technologies and hinder the diffusion of such technologies.

According to our empirical results, macroeconomic circumstances at the national level improve the spread of green technologies. Our findings suggest that the Popper theory, which proposes that democracy has a positive effect on the environmental-based technologies, is also applicable to the spreading of green technologies. All of the specifications mentioned in this thesis illustrate the dynamic nature of democracy. According to Wang et al. (2020), political freedom and institutional quality aid to lower carbon emissions when economic performance and financial development exacerbate environmental deterioration. Our finding is consistent with the results of Wejnert (2002) and Söderholm (2020).

On the other hand, our findings represent that socioeconomic conditions and foreign direct investment have positive connections with green technology diffusion. The spread of green technologies in a country can be facilitated by the technological capabilities, financial resources, and management practices that are brought in by foreign direct investments. Also, foreign direct investment promotes the shift to environmentally-friendly economy in low-income countries. Our finding aligns with the findings of Khan et al. (2020), whose research suggests a significant causal relationship between foreign direct investments, income levels, and environmental-based innovation. Socioeconomic conditions play a significant role in promoting the green products and technologies. This means that countries with more increased education, income, and human development tend to adopt and diffuse green technologies more rapidly. Furthermore, higher levels of education and income provide individuals and firms with greater knowledge, resources, and incentives to adopt and invest in green technologies.

In a similar vein, the diffusion of green technologies is positive correlation with general technology diffusion, technological advancements, and environmental performance. Specifically, general technology diffusion based on patents provides a basis of knowledge and resources that can be utilized for the creation and implementation of green technologies. Comparable findings have been reported by Comin and Mestieri (2014) and Jin (2016), suggesting that the spread of technological innovations can ease the shift to more sustainable productivity.

Moreover, energy-efficient and environmentally-friendly technologies can facilitate the environmental-based technologies. Our findings conclude that countries with higher environmental performance scores, indicating stronger environmental performance and low-carbon emissions, tend to adopt and diffuse green technologies more rapidly. These countries have a greater awareness of the benefits of green technologies and may be more willing to invest in them. Our finding is consistent with the results of Arbolino et al. (2018).

Our findings highlight that technological achievements have been a significant contributor to the progress of green technologies. TAI is a composite index that measures a country’s technological capabilities and development based on human skills, R&D investment, patents, and high-tech exports. A higher TAI score indicates that a country has greater technological development and capabilities, which can provide important foundations for the diffusion of environmental technologies. For example, TAI-higher countries may be better able to do research and create new environmentally friendly technology. They may also have greater access to financial resources and investments, which can support the adoption of green technologies. Additionally, countries with higher TAI scores may be better equipped to implement supportive policies and institutional frameworks that facilitate the diffusion of green technologies. Our finding aligns with the findings of Chaudhry et al. (2021).

Policymakers should take into account the implications of the findings of the study for the development of environmental-based technologies. This study reveals that technological achievements and the general diffusion of technology are crucial factors affecting the diffusion of green technologies. Environmental policies can create a favorable environment for the diffusion of green technologies and can incentivize firms to adopt more sustainable practices. However, policymakers should also consider the broader socioeconomic conditions and the distributional implications of environmental policies to ensure that they do not exacerbate inequality or negatively affect vulnerable groups.

Particularly, public investment in research and development is an essential policy tool for promoting the diffusion of green technologies. Governments can incentivize firms to invest in R&D by providing funding, subsidies, and tax credits. Additionally, environmental taxes can encourage firms to reduce their carbon footprint by imposing a tax on pollution or emissions. Preferential tariffs promote the improvement of green technologies by providing tariff reductions or exemptions for environmentally friendly products. Voluntary programs and environmental certificates are also effective policy tools for promoting the adoption of green technologies. These programs, such as energy efficiency programs, can provide incentives for firms to adopt green technologies by offering them access to technical assistance, training, and essential elements.

In summary, the results of empirical findings confirm the assertions made in existing literature, mostly regarding the economic and institutional indicators that impact the spread of environmentally-friendly technologies. However, this thesis goes beyond previous research by incorporating potential additional variables that influence the spread of such technologies. Moreover, this thesis broadens the scope of the literature by collecting data from a larger and more diverse sample of countries. Additionally, this thesis is the first to provide evidence that the diffusion and development of environmental technologies are contingent on both general and green technology trends, as well as the technological success of nations. The widespread adoption of green technologies in a country is influenced by factors such as general diffusion patterns and technological achievement levels.

3.3. GREEN GROWTH AND ENVIRONMENT SUSTAINABILITY

Green growth is a key driver in taking action to conserve the environment, and it has a significant impact on the public support that is needed. Understanding the notion of green growth as well as the factors that drive green growth is notably important against the severe obstacles facing green policies. This section will examine the empirical relationships and the function of various macroeconomic determinants on a national level that can potentially influence green growth. Therefore, the aim of this section is to provide a new overview to identify the improvements in green growth. The empirical results of this study indicate that countries improve environmental conditions by increasing investment in green technologies, adapting to climatic effects, and adopting low carbon emission policies for sustainable productivity and sustainable environment process. The issue of climatic conditions has become an importantly pressing concern in all over the world, as the rise in greenhouse gases threatens both the planet and humanity. The consequences and effects of climate change have far-reaching and potentially catastrophic outcomes for millions of people.

Green growth is a novel approach to economic performance that addresses climate and environmental issues. One of the goals of green growth is to promote economic growth and development while minimizing harmful impacts on the environment. This has been fueled by the recent financial crises and the increasing concerns about environmental and economic issues, leading to a renewed interest in environmentally responsible production and consumption within the framework of sustainable development.

More importantly, another goal of green growth is to create a more sustainable and equitable economy that can support the needs of current and future generations. This involves balancing the need for economic development and job creation with the need to protect the environment and essential elements. By adopting green growth strategies, countries can not only improve their environmental performance but also enhance their economic competitiveness and create new opportunities for growth and innovation.

Several factors may influence environmentally friendly expansion. Spreading environmental technology is a key factor in establishing green growth models and methods, for example. This shift toward a more sustainable and environmentally friendly economy has been aided by the widespread use of green technology. The acceleration of technological innovation is a key factor in green economic development. Greener economic expansion may be fostered through laws that incentivize environmentally responsible behavior on the part of firms and consumers. Tax credits and subsidies are two examples of monetary incentives that help spread the word about being green.

Another important determinant is environmental concerns. Growing awareness of environmental issues, such as climatic conditions, temperature, and resource depletion, acierates increased the demand for sustainable products and services. Likewise, social and economic values and differences in consumer behavior can also influence the improvement of green growth. In addition, public and private investment in R&D accelerates the creation of new technologies and products that are more environmentally friendly. Furthermore, collaboration and interconnectedness among countries facilitate the sharing of knowledge and resources, leading to more rapid development and adoption of green technologies and practices. Particularly, globalization is one of the important factors which refers to the increasing interconnectedness and interdependence of economic, social, and cultural systems around the world.

There are several ways in which globalization and green growth are related. Globalization facilitates the spread of environmentally-friendly technologies and practices, which accelerates countries' transition to more sustainable forms of economic growth. For instance, the global trade of green technologies and products can make these technologies more affordable and accessible to a wider range of countries and businesses.

The increasing transportation of people, products, and services associated with globalization can raise greenhouse gas emissions and hasten other types of environmental deterioration. In order to address these negative impacts, it is important for countries to work together and adopt policies that promote both globalization and green growth. This can include measures such as reducing tariffs and other barriers to trade in green technologies, supporting the improvement of renewable sources, and implementing regulations to reduce pollution and protect natural resources.

Finding solutions to boost economic performance and development while reducing harmful impacts on the environment is a central issue in the literature on green growth. The use of renewable energy sources, the encouragement of organic farming, agroforestry, and forestry techniques, and the enactment of rules to cut down on pollution and safeguard natural resources are all examples of possible tactics and policies. The necessity for international collaboration and coordination to properly handle environmental concerns is another prevalent subject in the green growth literature. Many of the environmental problems are global in scope and can only be properly handled with widespread collaboration and coordination across nations. The literature on green growth often emphasizes the importance of a more sustainable and fair method of economic development, as well as the possible advantages of doing so for the planet and the economy.

Green growth policies, in addition to these initiatives, are important for several reasons. Their primary function is to promote economic growth and development without jeopardizing environmental protection or the conservation of scarce natural resources. This is essential because, while economic development helps people all around the world live better lives, it must be done in a way that doesn't compromise the requirements of future generations. Climate change, biodiversity loss, and natural resource depletion are only a few of the major environmental concerns that may be mitigated by green growth strategies. These policies can successfully limit CO2 emissions and other types of environmental degradation and enacting laws to prevent pollution and safeguard natural resources.

Furthermore, green growth policies can also have positive social and economic impacts, such as creating new job opportunities, supporting local communities, and promoting innovation and technological development. Green growth policies may help people all around the world live better lives and build a brighter future by promoting an economy that is both sustainable and fair.

In light of the Green Solow Model, this section of chapter three investigates the role of green technology diffusion, climate change adaptation, and income level with causal factors on the progress of green growth. This study aims to provide an approach to environmental sustainability and is characterized by various factors. This section presents a study that focuses on three main objectives. The first objective is to examine the economic, political, environmental, and technological factors that contribute to the green growth index in OECD countries. The second objective is to address a significant gap in knowledge by exploring whether economic growth, green technologies, and climate change are also drivers of green growth. Thirdly, this study provides empirical evidence to support the theoretical literature on the Green Solow Model. Finally, we analyze using the System-GMM method to indicate the important role of factors in promoting the green growth process.

The rest of this section is organized as follows. Section one introduces the data and description the empirical model. Section two reports the empirical results of cross-sectional and panel data regressions. Lastly, section three summarizes the findings and concludes.

3.3.1. Data Description and Empirical Model

Concerns about the environment, accelerating economic growth, and sustainable development are all topics that have been the subject of extensive discussion. The concept of green growth is an important one in this context. The term “green growth” stood for a green economy, low carbon emissions, climate change conditions, and adaptation to green innovations and investments. On the other hand, due to the differences in historical context, economic development, and environmental deterioration, developing and developed countries are likely to take distinct paths toward green growth. This section describes the results of the preliminary analysis regarding the empirical analysis of green growth.

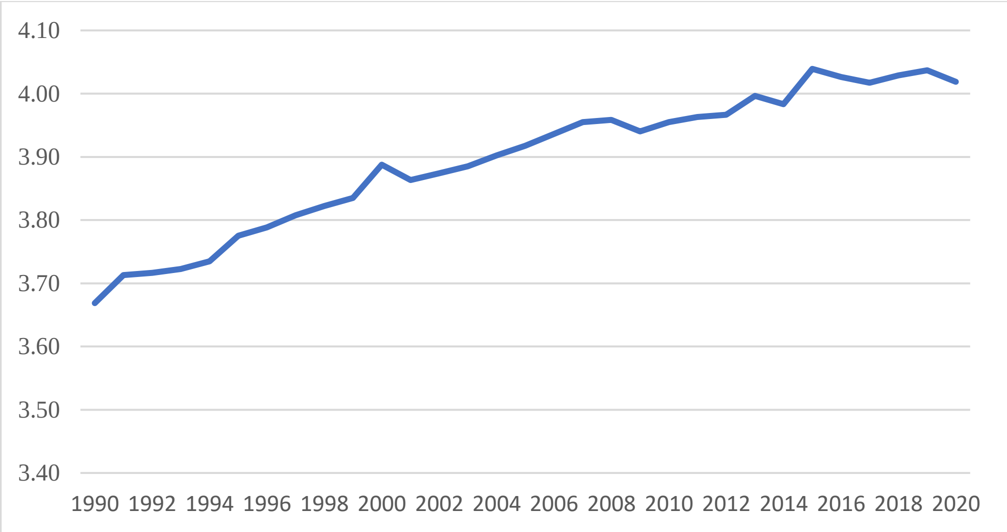
In accordance with a theoretical framework, the Mankiw-Romer-Weil model adds to the impact of climate change on economic growth by incorporating both short-term economic growth and long-term sustainable development. On the other hand, Brock and Taylor (2010: 127) developed the Green Solow model to examine the relationship between CO2 emissions and economic activity by extending the Solow growth model. They investigate the association between pollution, income per capita, and the EKC using the Solow model. In this section, we extend the analysis of the green Solow model to examine cross-country differences by considering socioeconomic, political, technological, climatic, and environmental variables.

This section aims to identify the impacts of potential variables such as the globalization effect, socio-economic conditions, economic and political values, climatic and technological progress, and environmental determinants on green growth. In previous studies, the panel estimation method is applied to a number of empirical determinants in achieving environmental sustainability (Vona and Patriarca, 2011; You, et al., 2015; Chin et al., 2018; Bilal et al., 2022), but not specifically to determinants of the green growth index. To our knowledge, there is no other study that has examined together the impact of such a wide range of potential factors on the green growth process. On the other hand, one support of this study is to examine the Green Solow Model, and its theoretical connections. Due to the data availability, this study covers OECD member countries which are shown in Appendix 1.

This section utilizes a dataset gathered from various sources. Fundamentally, the database of green growth indicators includes innovations related to the environment and technologies for adapting to climate change. The green growth index is calculated based on patent data related to green technologies, which are collected from the OECD patent database. The patent data used in this study play a crucial role in constructing a composite index that encompasses various dimensions of natural asset base, environmental and resource productivity, environmental quality of life, economic possibilities, policy reactions, and socio-economic conditions. To calculate the green growth index, a formula is used that takes into account the number of patent applications related to green technologies in a country, as well as the number of patents granted. A higher score indicates greater progress in green growth. The index is updated on an annual basis, allowing for tracking of progress over time. Figure 5 presents a plot of the average green growth index levels in selected countries from 1990 to 2020.

The climate change adaptation dataset is another variable used to assess the performance of countries and firms in terms of innovation, and it is also used to develop environmental and innovation policies by governments. This dataset is sourced from OECD statistics and is based on patent applications. The measure of economic growth used in this study is based on GDP per capita adjusted for purchasing power parity (PPP), which is obtained from the World Development Indicators (WDI) database by the World Bank. Moreover, the WDI database is utilized to calculate per capita carbon emissions and to collect information on foreign direct investment, which converts to a proportion of GDP, and population growth. The OECD statistics database is also used to obtain data on environmentally related tax revenues which converts to a proportion of GDP. Logarithmic representations of all of the data are used in the application.

Figure 5: Green Growth Index, 1990-2020



Source: Author's own calculations.

Moreover, government stability is obtained from the database of the Political Risk Services (PRS) Group. To assess the influence of patents on environmental advancements, the dataset compilation from the WIPO is utilized. The dataset related to the green technology diffusion is obtained from the patent database of the WIPO. Furthermore, the technology achievement index, which is a metric used to evaluate technological progress, has been determined by utilizing the approach introduced by Desai et al. (2002). To calculate this index, a dataset was compiled that takes into account four critical factors: the enhancement of human skills, the invention of new technology, the dissemination of old technology, and the propagation of new technology.

On the other hand, the environmental performance index is another variable taken into consideration when assessing a country's environmental sustainability and performance. This index takes into account a wide range of indicators, including factors such as air and water quality, greenhouse gas emissions, and natural resource management. The index is compiled by SEDAC which is a leading source of data and information on global environmental and socio-economic issues. Similarly, urbanization dataset is taken from SEDAC. Lastly, the KOF Globalization Index database is the source of the globalization index in our analysis. This index provides an overall assessment of globalization by averaging measures across the economic, social, and political dimensions.

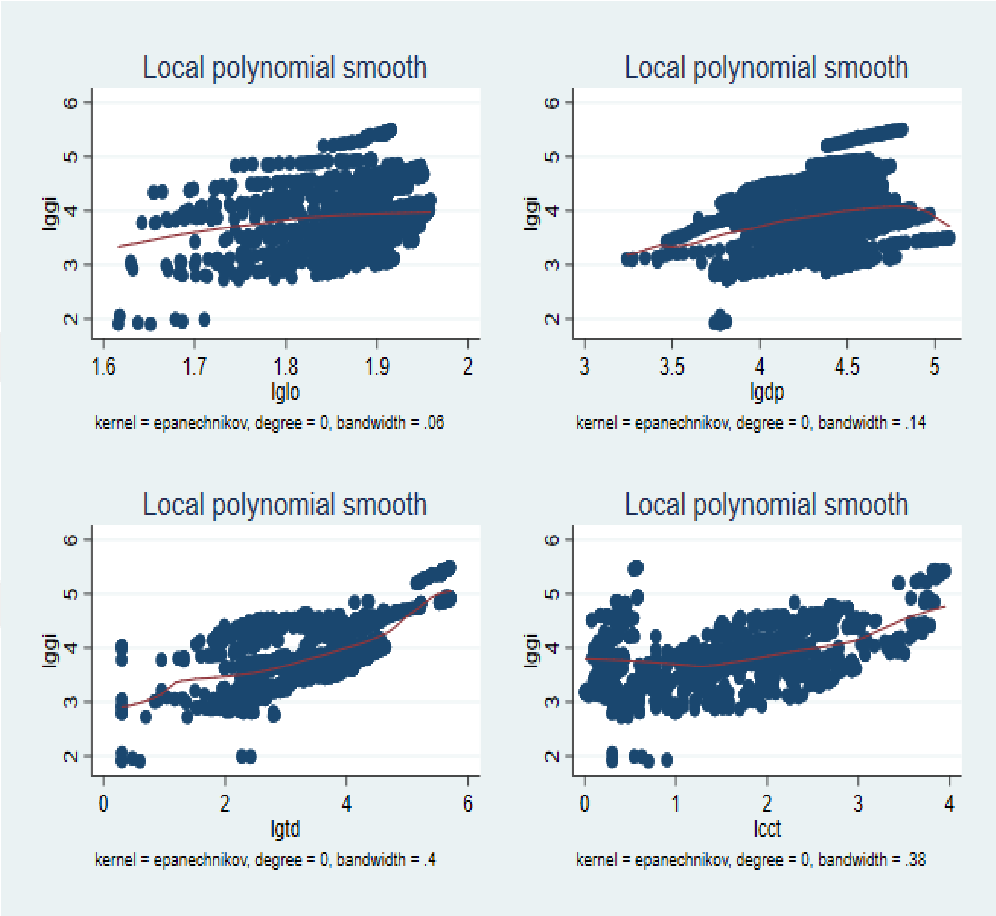
Figure 6 shows scatterplots of log of green growth index with log of globalization index, log of GDP per capita level, and log of climate change adaptation. These graphs display the fitted lines of linear, quadratic, cubic, and the 4th degree of polynomial regression along with the scatterplot. The first panel of the graph demonstrates a notable upward trend between the logarithm of globalization and the logarithm of green growth index, indicating that globalization has a positive influence on the environment. Increased globalization results in higher trade and economic growth, which can achieve to the development of environmental technologies and sustainable practices. This can ultimately decrease the environmental effects of economic activities and foster sustainable development.

The second panel of the graph displays a curved association between the log of economic growth and the log of green growth, indicating a potential positive correlation between the two variables until a certain inflection point is reached. This suggests that implementing sustainable development policies and practices may lead to both economic growth and environmental benefits.

The third panel of the graph shows a clear polynomial pattern with a higher average correlation between the logarithm of green technology diffusion and the logarithm of green growth index. This pattern suggests that the spread of green technology can have a beneficial effect on the environment and can help in attaining objectives related to sustainable development.

The fourth panel of the figure indicates that there exists a decreasing relationship between the logarithm of climate change adaptation and the logarithm of the green growth index up to a certain point. However, after reaching the turning point, an increase in the logarithm of climate change adaptation leads to an increase in the logarithm of green growth index. This suggests that efforts carried to minimize the environmental effect of economic activities and promote sustainable development can have positive effects on green growth. Additionally, scatterplots of each of these variables by country level over the years 1990 to 2020 are presented in Appendix 3.

Figure 6: Scatterplots of Green Growth Index, Globalization, Economic Growth, Green Technology Diffusion, and Climate Change Adaptation



Source: Author's own calculations.

Regarding the empirical model, this study takes a broader approach, investigating the impact of various indicators on green growth in a diverse set of global economies. Moreover, the study employs a dynamic system GMM model instead of static models to investigate these impacts. The System-Generalized Method of Moments (GMM) estimator used in this study is specifically designed for panels with "small *T*, large *N*", where there are few time periods and many individuals.

Following is the overall form of the model in the study:

$$ggi_{i,t} = f\begin{pmatrix} gdp_{i,t}, glo_{i,t}\, fdir_{i,t}, gov_{i,t}, co_{2\,i,t}, gtd_{i,t}, cct_{i,t}, epi_{i,t}, tax_{i,t}, tai_{i,t}, pop_{i,t}, \\ urb_{i,t}, cct_{i,t} * co_{2_{i,t}} \end{pmatrix} \quad (1)$$

where *ggi* represents green growth index as a dependent variable. The control variables are foreign direct investment (*fdir*), climate change adaptation (*cct*), GDP per capita (*gdp*), CO2 emissions as a metric ton per capita (co_2), government stability (*gov*), green technology diffusion (*gtd*), globalization index (*glo*), environmental performance index (*epi*), environmental-related tax (*ta*x), technology achievement index (*tai*), population growth (*pop*), interaction of climate change and CO2 emissions (*cct**co_2), and urbanization (*urb*). Natural logarithms are used for all variables. $t = 1, 2,...,T$ represents time in years, whereas $i = 1, 2,..., N$ means countries in the equation.

There are various studies that have contributed to the starting point of variable selection in our analysis. An information network for promoting green growth is provided by Georgeson et. al (2018). They mentioned the significance of various factors that make a contribution to the transition process of green growth and green products in developing and developed countries. On the other hand, Anser et al. (2019) have established a cause-and-effect connection between the growth of GDP and the emission of carbon, and they discovered a mutual relationship between the increase in economic growth and the consumption of energy. Furthermore, several studies (Aye et al., 2017; Chin et al., 2018) have implied that factors such as income level, CO2 emissions, environmental performance, climate conditions, and innovation play a critical role in improving the green growth process.

The FDI of countries is another selected factor in our analysis. Previous studies have found that open trade and investment profile have significant contributor on green growth progress, as indicated by Zafar et al. (2020). This finding is consistent with Khan et al. (2020). Another selected factor based on the current literature is the globalization index. An example from the current literature by Xia et al. (2022) find a significant positive relationship between globalization and carbon emissions, with GDP growth also contributing to increased carbon emissions.

Lastly, Samad and Manzoor (2015) conclude that on the progress of environment performance, R&D spending, green technology, and environment-related tax show a significant impact. Additionally, Antal and Van Den Bergh (2016) concludes that green regulations decrease the effects of climate change and environmental risks in the context of environmental sustainability. This finding is consistent with other studies (Yuan and Xiang, 2018; Meng et al., 2020; Bo et al., 2022). Conversely, He et al. (2022) argue that environmental implementation has a negative impact on green growth. Our study extends the current literature by expanding the number of countries and the number of variables analyzed, encompassing both developing and developed nations.

The dynamic panel model is formulated with the assumption that there is a linear association between the variables, and thus takes the following specific form:

$$
\begin{aligned}
ln(ggi)_{i,t} = \alpha_0 + \sum_{j=1}^{p} \rho_i \, lnggi_{i,t-j} + \alpha_1 lngdp_{i,t} + \alpha_2 lnglo_{i,t} + \alpha_3 lnfdir_{i,t} \\
+ \alpha_4 lngov_{i,t} + \alpha_5 lnco_{2_{i,t}} + \alpha_6 lngtd_{i,t} + \alpha_7 lncct_{i,t} + \alpha_8 lnepi_{i,t} \\
+ \alpha_9 lntax_{i,t} + \alpha_{10} lntai_{i,t} + \alpha_{11} lnpop_{i,t} + \alpha_{12} lnurb_{i,t} + \theta lncct_{i,t} \\
* lnco_{2_{i,t}} \eta_{i,t} \\
+ \varepsilon_{i,t} \qquad (2)
\end{aligned}
$$

$$\varepsilon_{i,t} = \eta_i + v_{i,t} \,, \; E(\eta_i) = 0, \; E(v_{i,t}) = E(\upsilon_{i,t}\eta_i) = 0$$

Equation (2) includes an error term denoted as $\varepsilon_{i,t}$ that is made up of two distinct and independent components, namely the fixed effects component η_i and the idiosyncratic shocks component $v_{i,t}$. Also, the value of q represents the order of autocorrelation in the equation.

The significant correlation between the variables, as seen in Table 10, may be challenging to estimate the entire variables in Equation (2) because of multicollinearity. This makes it difficult to determine the independent effect of each variable on the dependent variable. As a result, it is necessary to apply restrictions to the model or exclude some variables to address the issue of multicollinearity and obtain more accurate estimates of the model coefficients. Therefore, the study employs various restrictions to Equation (2) and estimates six different versions of the model. Table 8 provides details on the model specifications, exclusion constraints, and variables used in each model.

The GMM approach for estimation is suitable for cases where there are potential endogeneity issues, such as in the case of panel data analysis. It is useful when the errors are correlated with one or more of the explanatory variables, leading to biased and inconsistent estimates of the coefficients. In order to ensure that the results of the six models generated using the two-step system GMM approach are valid, several diagnostic tests were conducted. The first step involved examining the correlation pairs and multicollinearity in the data using the variance inflation factor. Next, the study performed autocorrelation tests (Arellano and Bond, 1991) to check for serial correlation in the errors. Furthermore, to assess the validity of the instrumental variables used in our models, we test overidentifying restrictions (Sargan, 1958). This test determines if the instruments used in the estimation are valid and whether the chosen sample size is sufficient to yield reliable results.

Table 8: Model Specifications

Model name	**Exclusion constraint**	**Excluded indicators**	**Indicated association**
Model 1	$\alpha_3 = \alpha_4 = \alpha_5 = \alpha_8 = \alpha_9 = \alpha_{10} = \theta = 0$	*fdir, gov,* co_2*, epi, tax, tai, cct**co_2	*ggi* =f(*gdp, glo, gtd, cct, pop, urb*) + ε
Model 2	$\alpha_4 = \alpha_5 = \alpha_8 = \alpha_9 = \alpha_{10} = \theta = 0$	*gov,* co_2*, epi, tax, tai, cct**co_2	*ggi* =f(*gdp, glo, gtd, fdir, cct, pop, urb*) + ε
Model 3	$\alpha_2 = \alpha_5 = \alpha_8 = \alpha_9 = \alpha_{10} = \theta = 0$	*glo,* co_2*, epi, tax, tai, cct**co_2	*ggi* =f(*gdp, gtd, cct, fdir, gov, pop, urb*)+ ε
Model 4	$\alpha_2 = \alpha_7 = \alpha_8 = \alpha_9 = \alpha_{10} = 0$	*glo, epi, tax, tai*	*ggi* =f(*gdp, gtd, cct, fdir, gov,* co_2 *, pop, urb, cct**co_2)+ ε
Model 5	$\alpha_2 = \alpha_{10} = 0$	*glo, tai*	*ggi* =f(*gdp, gtd, cct, fdir, gov, epi, tax, pop, urb, cct**co_2)+ ε
Model 6	$\alpha_2 = 0$	*glo*	*ggi* =f(*gdp, gtd, cct, fdir, gov,* co_2 *, epi, tai, tax, pop, urb,*

Table 9 presents a summary of statistical information for all variables, based on the descriptive statistics. These include the mean, standard deviation, minimum, and maximum values of each variable. The total number of observations (*n*) has 1,178 individual data. All variables in the analysis are reported in logarithmic form. The initial column of the table displays the names of the indicators in logarithmic levels within the panel.

Table 9: Descriptive Statistics

Variables	Obs.	Mean	Std. Dev.	Min.	Max.
		Log Levels			
LGGI	1,178	3.895	0.582	1.904	5.508
LGDP	1,178	4.356	0.299	3.239	5.082
LGLO	1,178	1.878	0.067	1.616	1.959
LFDIR	1,178	2.259	0.097	1.841	2.474
LGOV	1,178	0.876	0.091	0.477	1.045
LCO2	1,178	0.842	0.253	0.080	1.440
LGTD	1,178	3.461	1.031	0.301	5.714
LCCT	1,178	1.576	1.045	0.001	3.952
LEPI	1,178	1.796	0.072	1.502	1.957
LTAX	1,178	0.365	0.180	0.002	1.820
LTAI	1,178	0.334	0.131	0.093	0.818
LPOP	1,178	7.087	0.651	5.401	8.517
LURB	1,178	2.255	0.334	0.368	2.666

Table 10 presents the results of the Pearson pairwise correlation matrix between the independent and control variables, which was conducted to measure the correlation coefficient estimates among them. This test is valuable for assessing the level of correlation among variables. The correlation coefficient of government stability is negatively related to the green growth index, while the other independent variables are positively correlated with it. All of these factors are the primary contributors and can potentially lead to an increase in green growth. On the other hand, there are many pairs of variables representing high correlation: GDP per capita and environmental performance index, GDP per capita and globalization index, technology achievement index and environmental performance index, technology achievement index and green technology diffusion, globalization index and environmental performance index, globalization index and green technology diffusion, globalization index and technology achievement index, climate change adaptation and environmental performance index, and lastly environmental-related tax and environmental performance index.

Table 10: Correlation Matrix

	LGGI	LGDP	LGLO	LFDIR	LGOV	LCO2	LGTD	LCCT	LEPI	LTAX	LTAI	LPOP	LURB
LGGI	**1.00**												
LGDP	**0.52**	**1.00**											
LGLO	**0.48**	**0.77**	**1.00**										
LFDIR	**0.10**	**0.34**	**0.38**	**1.00**									
LGOV	-0.06	**0.07**	**0.09**	0.03	**1.00**								
LCO2	**0.52**	**0.52**	**0.42**	**-0.05**	**0.16**	**1.00**							
LGTD	**0.74**	**0.55**	**0.60**	**0.20**	**0.05**	**0.45**	**1.00**						
LCCT	**0.78**	**0.20**	**-0.16**	**-0.19**	**0.15**	**0.16**	**0.26**	**1.00**					
LEPI	**0.02**	**0.66**	**0.54**	**0.15**	**-0.09**	**0.23**	**0.33**	**-0.52**	**1.00**				
LTAX	**0.64**	**0.05**	**0.05**	**0.07**	**0.02**	**0.03**	**-0.21**	**-0.08**	**0.49**	**1.00**			
LTAI	**0.41**	**0.61**	**0.54**	**0.08**	**0.15**	**0.46**	**0.65**	**0.15**	**0.67**	-0.17	**1.00**		
LPOP	**0.89**	**-0.07**	**0.00**	**0.03**	**-0.14**	**-0.12**	**0.54**	**0.44**	**-0.21**	**-0.31**	**0.18**	**1.00**	
LURB	**0.49**	**0.15**	**0.22**	-0.02	**-0.15**	**0.46**	**0.42**	**0.35**	**0.40**	**0.48**	**0.56**	**0.68**	**1.00**

Note: The boldface denotes to 1% significance level.

3.3.2. Empirical Results

This section will concentrate on examining how globalization, income level, technology diffusion, and other explanatory variables affect the green growth of OECD member countries. The main goal of this study is to explore the effects of different economic, and environmental values on environmental sustainability and the green growth process, with a particular emphasis on analyzing the role of environmental technologies and climatic effects. This section provides evidence on the role of selective variables in green growth by using cross-sectional regression models. To achieve this, we employ six different models. In addition, we will test for cross-sectional dependence, and the presence of stationary. The following lines will detail the results and implications of these estimations.

Table 11 reports the statistical outcomes of the cross-sectional dependence (CSD) tests. CSD refers to the correlation between observations in a dataset. When observations in a dataset are not independent of each other, it can have an impact on the accuracy of statistical tests and lead to incorrect conclusions. We use three tests for CSD tests: Breusch and Pagan (1980) LM (Lagrange Multiplier) Pesaran (2004) Scaled LM test, and Pesaran (2004) CD test. Additionally, we also test for slope heterogeneity in the data series with the Pesaran and Yamagata (2008) standardized version of the Swamy (1970) homogeneity test (delta tests). The green growth index represents as the dependent variable in all the models used in the analysis. Each of models include the variables globalization index, GDP per capita, population, urbanization, green technology diffusion, technology achievement index, and climate change adaptation, but each also includes one of the variables carbon emissions, government stability, foreign direct investments, environmental-related tax, and environmental performance index as independent variables, respectively.

Table 11: Cross-sectional Dependence Test

CSD Tests	Statistic	*p*-value	Statistic	*p*-value
	Model 1		***Model 4***	
LM	393.895*	0.000	299.657*	0.000
CD	128.57*	0.000	103.36*	0.000
CD_{LM}	19.011*	0.000	13.889*	0.000
Homogeneity Tests				
$\tilde{\Delta}$	0.832	0.406	0.588	0.556
$\tilde{\Delta}_{adj}$	1.126	0.260	0.796	0.426
	Model 2		***Model 5***	
LM	366.489*	0.000	429.607*	0.000
CD	140.75*	0.000	93.16*	0.000
CD_{LM}	15.329*	0.000	9.623*	0.000
Homogeneity Tests				
$\tilde{\Delta}$	1.103	0.270	0.251	0.802
$\tilde{\Delta}_{adj}$	1.493	0.135	0.340	0.734
	Model 3			
LM	291.048*	0.000		
CD	66.56*	0.000		
CD_{LM}	11.147*	0.000		
Homogeneity Tests				
$\tilde{\Delta}$	-0.735	0.512		
$\tilde{\Delta}_{adj}$	-0.831	0.335		

Note: The symbol * denotes the significance at the 1% level.

As seen in Table 11, the null hypothesis of no cross-sectional dependence is rejected in Model 1-5. These findings highlight the presence of cross-sectional dependency in the data. Given the cross-sectional dependency of the data, it is necessary to employ second-generation unit root tests. Moreover, we fail to reject the null hypothesis of slope homogeneity across nations at any of the assumed significance levels. Therefore, it is improbable that the slope would differ between countries.

We utilize second-generation panel unit root tests. These tests allow us to assess whether our variables are stationary or not. Multiple panel unit root tests are used in this study to ensure robustness and consistency. Specifically, we utilize the cross-section augmented Im-Pesaran-Shin (CIPS) test proposed by Pesaran (2007), and the cross-section augmented Dickey-Fuller (CADF) test introduced by Pesaran (2003). These tests incorporate additional factors or lag into the model to enhance the accuracy of the unit root analysis.

Table 12 displays the results of the second-generation panel unit root tests, and the findings reveal that for all variables, the null hypothesis of a unit root is rejected at 1% and 5% levels. This suggests that all variables are stationary at the level and trend. Dynamic models are used when the dependent variable is influenced by its past values or lags of the independent variables. In other words, the current value of the dependent variable is not only affected by the current values of the independent variables but also by their past values. This type of relationship between variables is often referred to as autocorrelation. In these cases, it is often necessary to use a model that accounts for the fact that the data is not independent over time. We use dynamic GMM models to allow us to capture the evolution of the broad range of variables over time and better understand the underlying relationships between them.

The model is able to address the issue of unobserved country-specific heterogeneity, as both country-time effects and country-fixed effects were observed, in line with model predictions. In this study, the findings of the Durbin-Wu-Hausman test indicate that some of the independent variables are indeed endogenous, highlighting the need to account for this endogeneity in the analysis. We use dynamic panel GMM estimators which were suggested by Arellano and Bond (1991) to reduce issues of serial correlation and heterogeneity. This method identifies and addresses the endogeneity concerns.

Table 12: Panel Unit Root Tests

	Constant		***Constant and Trend***	
Variable	CIPS	CADF	CIPS	CADF
LGGI	-3.215***	-2.021 ***	-3.784***	-2.011**
LGDP	-2.217***	-2.452***	-2.451*	-2.145***
LGLO	-2.807***	-2.141**	-3.784***	-2.540***
LFDI	-3.546***	-2.451***	-3.654***	-4.454**
LGOV	-3.125***	-2.562***	-3.451***	-3.132***
LCO2	-2.174*	-1.784*	-2.256**	-2.221*
LGTD	-2.218***	-2.454***	-2.541*	-2.441**
LEPI	-2.097**	-2.012***	-3.314**	-2.761**
LCCT	-2.315***	-1.507*	-3.173**	-2.796**
LTAX	-2.124**	-1.401	-1.804*	-2.854*
LTAI	-2.547**	-2.029**	-2.774**	-2.614*
LPOP	-1.641	-2.175***	-1.945*	-2.781**
LURB	-2.457***	-3.014***	-5.015**	-3.895**

Note: The symbols **, and * refer to the 1% and 5% significance levels.

There are several reasons to use the System-GMM method. First of all is the endogeneity issue. When some of the explanatory variables are correlated with the error term in the model, they lead to biased and inconsistent estimates. We will employ a dynamic panel model. It is mainly utilized when the dependent variable has a lagged effect on itself or some of the explanatory variables have a lagged effect on the dependent variable. Another reason is that the number of cross-sectional units is large relative to the time periods (large N, and small T). Moreover, we have all the variables in the model to be stationary over time.

This method addresses some of the issues that arise in panel data analysis, such as endogeneity, omitted variable bias, and measurement error, by using a combination of level and first-difference estimators and instrumental variables. We have a cross-sectional dimension (N) is 38 and a time dimension (T) is 30, ($T< N$) as recommended by Baltagi (2021). To assess the dynamic specification of the model, we employ the Arellano-Bond autocorrelation tests. These tests examine whether there is any serial correlation present in the model's errors. Additionally, we evaluate the validity of the instrumental variables used in the analysis using the Sargan-Hansen J-test. This test is conducted for both the level and first-differenced models to ensure that the instrumental variables satisfy the necessary conditions and do not introduce any bias into the estimation.

Given the features of the panel data framework, due to overfitting, multicollinearity, autocorrelation, and endogeneity, all possible variables are not included in each model in our analysis. Instead, alternative combinations of variables are included as seen in Table 8. The estimation technique employed in this study, known as dynamic system GMM estimation with one lag, is used to assess the presence of serial correlation in the data. The results of the Arellano-Bond tests (AR(1)) indicate a significant rejection of the first-order serial correlation assumption, suggesting the existence of autocorrelation in the model. However, the AR(2) tests do not consistently reject the second-order serial correlation assumption at the 5% and 1% significance levels, indicating that the AR(2) specification may not be valid. Therefore, to account for autocorrelation, we include a lagged dependent variable in all model specifications. The Sargan-Hansen J-test indicates that results indicate that the null hypothesis, which assumes that the instrumental variables are valid, cannot be rejected for any of the models. This finding implies that the instrumental variables employed in the analysis are valid.

The GMM estimator is capable of removing cross-sectional dependence while ensuring that the results remain consistent, in line with the definitions set by Sarafidis (2009) and Sarafidis and Wansbeek (2012). Similarly, it is possible to obtain a reliable GMM estimator by using a subset of parameters that rely on exogenous instruments. The residuals of the system GMM estimates were tested for cross-sectional dependence using the CD(ρ) test, and the results are shown in Table 13. This test confirms that the GMM estimator is effective in handling all cross-sectional dependencies in the data, and the conclusions drawn from GMM estimations remain valid.

Our study in this section examines possible factors that can influence the green growth index. Table 13 presents the results of the dynamic panel estimations conducted for six different model specifications in OECD countries. The base model is Model 1 in this study assesses how economic growth, globalization effect, adaptation to climate change, and green technology diffusion factors impact green growth. The model also includes population and temperature as control variables. The findings reveal that all coefficients of factors have a significant and positive contributor the progress of green growth in OECD countries. Green growth aims to improve economic productivity and efficiency while also reducing the utilization of natural resources, minimizing waste, and decreasing pollution. This positive relationship is important in achieving environmental sustainability. On the other hand, the use of green technologies not only helps in decreasing the emission of greenhouse gases and mitigating other environmental impacts but also offers economic benefits, including enhanced efficiency and productivity.

Economic growth in OECD countries has a positive impact on the green growth process for several reasons. First, the additional financial resources from economic growth enable greater investments in sustainable technologies and innovations that reduce environmental impacts. Second, as economies grow, there is a stronger incentive to optimize resource use and minimize waste, leading to greater resource efficiency. Third, economic growth allows governments to implement and enforce more stringent environmental policies and regulations, compelling businesses to adopt greener practices. Fourth, the expansion of economies attracts investment into green sectors, further promoting sustainable development. Lastly, rising public awareness and demand for eco-friendly products and services drive businesses to adopt more sustainable practices, accelerating the transition towards a greener and more sustainable future.

Furthermore, we find that there is also a positive relationship between population and green growth. A larger population often leads to increased economic activity and consumption, which can drive innovation and investment in green technologies and sustainable practices. Urbanization and green growth have a positive relationship due to various factors. Particularly, urban areas serve as centers of innovation and technological advancement, enabling the development and adoption of green technologies.

Model 2 examines the effects of foreign direct investment on the advancement of green growth. The findings represent a substantial and favorable interaction between foreign direct investment and the promotion of green growth. The study identifies multiple ways in which foreign direct investment can support green growth and expertise necessary for developing and executing green growth strategies.

Additionally, foreign direct investment can promote job creation and economic growth, providing resources to invest in green growth initiatives. Lastly, foreign direct investment can facilitate international collaboration and partnerships that can advance environmental sustainability.

In Model 3, the focus is on examining the effect of governmental factor on the advancement of green growth. The findings reveal a noteworthy and optimistic connection between government stability and green growth. This suggests that the presence of a stable and efficient government have a crucial role in fostering the adoption of sustainable practices, promoting renewable energy sources, and mitigating environmental degradation.

In Model 4, we investigate the effects of CO2 emissions and also the interaction term between carbon emissions and climate change adaptation. First of all, we observe that CO2 emissions have a favorable effect on the green growth process. This implies that as countries experience higher levels of green growth, there is a corresponding increase in carbon emissions. This can be attributed to the fact that as economies grow and industries expand, there is often an accompanying rise in energy consumption, leading to increased carbon emissions. However, this positive relationship does not necessarily indicate a lack of environmental sustainability. It suggests that as countries prioritize green growth, they also need to implement policies and adopt technologies that promote cleaner and more efficient energy production, reduce carbon intensity, and transition towards low-carbon and renewable energy sources. Countries can achieve a sustainable and environmentally friendly economic development pathway by efficiently controlling carbon emissions while pursuing green growth.

Moreover, we also observe that interaction term between CO2 emissions and adaptation to climatic conditions has a detrimental effect on green growth process. The finding implies that the effectiveness of climate change adaptation strategies in promoting green growth is diminished in the presence of higher carbon emissions. This suggests that as carbon emissions increase, the adverse impacts of climate change become more severe, hindering the progress of green growth initiatives. It stresses the need of reducing carbon emissions and mitigating climate change drivers, as well as the necessity for governments to prioritize climate change adaptation measures. Therefore, carbon emissions have an indirect negative effect on green growth progress.

By addressing both carbon emissions and climate change adaptation in tandem, countries can better promote sustainable economic growth while simultaneously building resilience to the impacts of climate change.

In Model 5, we include the environmental performance index the model. We find that environmental performance has a considerable impact on green growth, suggesting that nations with higher environmental performance likely to make larger strides toward attaining sustainable and environmentally friendly economic growth. Moreover, environmental-related tax is also added to Model 5. There is also a positive association between environmental-related taxes and green growth. This finding suggests that implementing such taxes can contribute to the promotion of sustainable and environmentally-friendly economic development.

Model 6 includes the technology achievement index, which represents the most extended model. We find that there is a positive relationship between the technology achievement index and green growth suggesting that advancements in technology play a crucial role in promoting sustainable economic development. The technology achievement index reflects a nation’s capacity to invent and adopt new technologies that contribute to environmental preservation, resource efficiency, and greenhouse gas reduction.

Table 13: Dynamic Panel Estimations (system-GMM) for Various Model Specifications of Green Growth

Variables	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
L.LGGI	0.3501***	0.3559***	0.3811***	0.3670***	0.3641***	0.3654***
	(0.002)	(0.011)	(0.009)	(0.009)	(0.012)	(0.014)
LGDP	0.2077***	0.2301***	0.2601***	0.2623***	0.2547***	0.2479***
	(0.007)	(0.003)	(0.002)	(0.007)	(0.009)	(0.009)
LGLO	0.2108***	0.1877***				
	(0.003)	(0.034)				
LFDIR		0.0030***	0.0032***	0.0055***	0.0073***	0.0054***
		(0.000)	(0.001)	(0.001)	(0.001)	(0.001)
LGOV			0.0895***	0.0805***	0.0831***	0.0711***
			(0.003)	(0.000)	(0.005)	(0.005)
LCO2				0.1922***	0.1517***	0.1504***
				(0.017)	(0.016)	(0.010)
LGTD	0.0411***	0.0425***	0.0497***	0.0385***	0.0381***	0.0349***
	(0.000)	(0.000)	(0.001)	(0.003)	(0.002)	(0.002)
LEPI					0.0563***	0.0393***
					(0.008)	(0.001)
LCCT	0.0039***	0.0055***	0.0044***	0.0103***	0.0083***	0.0071
	(0.001)	(0.001)	(0.001)	(0.005)	(0.001)	(0.000)
LTAX					0.0502***	0.0511***
					(0.011)	(0.011)
LTAI						0.0695***
						(0.010)
LPOP	0.4661***	0.4497***	0.4478***	0.4567***	0.4701***	0.4745**
	(0.011)	(0.012)	(0.010)	(0.009)	(0.016)	(0.020)
LURB	0.3154***	0.3301***	0.3468***	0.3877***	0.3921***	0.4152***
	(0.001)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)
CCT*CO2				-0.014***	-0.009***	-0.008***
				(0.006)	(0.005)	(0.005)
Constant	-2.512***	-2.4213***	-2.8978***	-2.4587***	-2.6144***	-2.5754***
	(0.106)	(0.009)	(0.006)	(0.083)	(0.105)	(0.1272)
N	1140	1140	1140	1140	1140	1140
χ^2	578124.17***	422457.02***	497515.33***	417670.28***	512454.02***	572214.01***
AR (1)	-1.7122**	-1.7562**	-1.7327**	-1.7964**	-1.7893**	-1.7991**
AR (2)	0.4421	0.4124	0.3875	0.6418	0.7629	0.2733
Sargan *J* stat.	37.2487	37.1245	37.0154	36.6078	36.3117	36.2662
CD(ρ)	0.917	1.215	1.222	1.117	1.231	1.614

Note: The standard errors displayed in parentheses. The number of observations is denoted by N, while χ^2 is the Chi-square statistic used to test the joint significance of all slope parameters. * denotes significance at 10%, ** denotes significance at 5% and *** denotes significance at 1%.

3.3.3. Concluding Remarks

This section exhibits the empirical effects of a variety of potential influences on the green growth index. Therefore, we assess separately each of the determinants in six models. To address concerns related to overfitting, multicollinearity, autocorrelation, and endogeneity, we employ the System-GMM estimation method. This approach provides a robust way to estimate the model parameters while taking into account these issues. By utilizing GMM, we can effectively mitigate potential biases and improve the accuracy of our parameter estimates.

First of all, the main determinants of the green growth such as spreading of green technologies, income level, and adaptation to climatic events have a significant and positive interaction with green growth. We conclude the positive association between economic growth and green growth suggests that as economies expand and become more prosperous, there is an increased capacity to invest in and adopt environmentally friendly practices and technologies. Economic growth provides the financial resources and incentives for renewable energy investment, energy efficiency measures, sustainable infrastructure, and environmentally conscious production processes. It creates opportunities for job creation in green sectors and stimulates innovation and research in clean technologies. Additionally, as countries experience economic growth, there is often an improvement in education, awareness, and environmental regulations, which further promote sustainable development and green practices. Moreover, economic growth can lead to higher living standards, which in turn may increase demand for a clean and healthy environment. We reveal the positive relationship between green technology diffusion and green growth. Therefore, the adoption and utilization of green technologies contribute to the advancement of sustainable economic growth. When green technologies, which encompass environmentally friendly and resource-efficient solutions, are disseminated and integrated into various sectors, they promote sustainable practices, reduce environmental impact, and enhance resource efficiency. This leads to improved productivity, cost savings, and innovation, all of which contribute to economic growth. In addition, the proliferation of green technologies fosters the growth of new sectors, job creation, and technical improvements, so facilitating the transition to a low-carbon and sustainable economy. The association between climate change adaptability and green growth is shown to be beneficial. This conclusion is based on the realization that addressing and adapting to climate change concerns and mitigating their effects can generate possibilities for sustainable economic growth. Adaptation to climate change entails implementing strategies and actions to minimize susceptibility and increase resilience to the effects of climate change, such as extreme weather events and shifting environmental circumstances. These adaptation efforts often require investments in renewable energy, energy efficiency, sustainable agriculture, water management, infrastructure resilience, and other green technologies and practices. By incorporating climate change adaptation into their development plans and strategies, nations may increase their capacity to deal with climate threats while simultaneously fostering green growth. Climate-resilient infrastructure and practices not only protect communities and ecosystems but also contribute to job creation, innovation, and long-term economic sustainability. Furthermore, proactive adaptation measures can help minimize future damages and costs associated with climate change impacts, leading to more efficient resource use and improved economic outcomes.

Our empirical findings reveal that globalization, characterized by increased international trade, investment, and economic integration, has a significant contributor to green growth. The finding suggests that the increasing interconnectedness and integration of economies across the globe in promoting sustainable economic process. Globalization facilitates the transfer of knowledge, technology, and resources, which are essential for the adoption and diffusion of green technologies. It enables countries to access and learn from best practices, innovation, and experiences in sustainable development from around the world. Globalization also expands market opportunities and enhances international trade, creating avenues for the export and dissemination of green products and services. Furthermore, globalization encourages collaboration and cooperation among nations, leading to collective efforts in addressing environmental challenges and implementing sustainable policies.

Moreover, population and urbanization indicators also have a positive relationship with the green growth progress. A larger population can provide a diverse and skilled labor force, supporting the development and deployment of green technologies. Finally, a growing population can increase awareness and concern for environmental issues, leading to greater support for environmental policies and initiatives. Therefore, a larger population can contribute to green growth by fostering innovation, economies of scale, a skilled workforce, and public support for sustainability measures. On the other hand, the compact nature of urban cities promotes resource efficiency, leading to reduced energy consumption and better utilization of resources. Urban areas also offer better access to services and infrastructure, facilitating sustainable practices and improving quality of life. Strong governance structures and policies in cities prioritize environmental sustainability, while urban populations exhibit higher demand for environmentally friendly products and services, driving businesses to adopt sustainable practices. Overall, urbanization creates conditions for green growth through innovation, resource efficiency, access to services, supportive policies, and market demand.

According to our empirical analysis, we reveal that FDI has significantly contributed to the green growth process that FDI inflows have a beneficial impact on the development and promotion of sustainable and environmentally friendly practices. When foreign investors invest in a country, they often bring along advanced technologies, knowledge, and expertise, which can contribute to the adoption of cleaner production processes and renewable energy sources. Additionally, FDI can stimulate economic growth and create employment opportunities, leading to higher incomes and increased demand for environmentally friendly products and services. Furthermore, foreign investors may also prioritize environmental sustainability and require adherence to environmental standards, thereby encouraging host countries to adopt and enforce stricter environmental regulations. Overall, FDI can contribute to the advancement of green growth by fostering innovation, promoting sustainable practices, and driving economic development.

We also conclude that government stability has a significant contributor to progress of green growth. The finding indicates that a stable political environment is conducive to the promotion and implementation of policies and initiatives that support sustainable development and environmental protection. When a government is stable, it can provide a consistent and predictable regulatory framework, which encourages businesses and investors to engage in green practices and invest in environmentally friendly technologies. Stable governments are also more likely to prioritize long-term sustainability goals and allocate resources effectively toward environmental initiatives. They can develop and implement comprehensive strategies to address environmental challenges. Additionally, stable governments are better equipped to collaborate with international organizations, engage in global environmental agreements, and attract international funding for green projects.

In the progress of green growth, when a country performs well in terms of environmental indicators, it creates a conducive environment for green initiatives and investments. Our empirical findings represent a higher EPI score is leading to positive outcomes for green growth. Strong environmental performance reflects a commitment to sustainable practices, which can attract green technologies, and investments, and promote sustainable consumption and production patterns. It also signifies that the country has effective policies and regulations in place to protect the environment and promote sustainable productivity. Our findings also reveal that environmental-related taxes have a significant contributor to progress of green growth highlights the potential of fiscal instruments in promoting sustainable and environmentally-responsible economic activities. Carbon taxes and pollution levies are two examples of environmental-related taxes that aim to achieve just that by making the costs of environmental degradation internalized and therefore encouraging cleaner and more sustainable practices among businesses and individuals. Governments can encourage citizens to minimize harmful emissions, adopt more environmentally friendly technology, and better protect natural resources by taxing activities that have disastrous consequences on the environment. As a result, it’s possible that green technology will advance, green jobs will be created, and sustainable businesses will expand.

Moreover, our findings highlight that CO2 emissions have a significant contributor to the green growth process. This finding implies that as an economy experiences growth and development, there is typically an increase in carbon emissions. However, the positive relationship does not necessarily suggest that green growth is solely dependent on increasing carbon emissions. Instead, it stresses the need to use eco-friendly methods and innovative technology to decreasing the impact of economic performance on the natural world. The goal is to have economic development without a corresponding rise in carbon emissions, a phenomenon known as "decoupling." Promoting renewable energy, energy efficiency, waste reduction, and responsible resource management is at the heart of green growth programs. These policies allow countries to reduce their carbon footprint and address environmental problems without slowing down their economic growth. This finding underlines the need for deliberate policies and investments that advance sustainable development and the shift to a low-carbon economic system.

More importantly, we demonstrate that the progress of green growth is negatively impacted by the interaction term between carbon emissions and climate change, implying that the efficacy of climate change adaptation measures may be impaired in the context of high carbon emissions. The negative effects of climatic conditions, such as rising temperatures, and ecological disturbances, can be exacerbated by high amounts of carbon emissions. As a result, these effects pose serious difficulties for sustainable development and slow down green growth. Climate change adaptation methods that lower vulnerability to climate-related hazards are therefore essential. When the carbon emissions and climate change adaptation interaction is negative, however, it suggests that the negative effects of high carbon emissions may mitigate or surpass the good effects of adaptation efforts on green growth. Sustainable and resilient green growth depends on comprehensive plans that address both lowering carbon emissions and effectively adapting to climatic effects.

Apart from the aforementioned considerations, the technology achievement index measures a country’s performance in R&D, patent activity, and the uptake of new technologies. When countries prioritize and invest in technological advancements related to green technologies for promoting green growth. These technologies help reduce environmental impacts and enhance resource efficiency. By fostering a conducive environment for technological innovation and knowledge transfer, countries can unlock new economic opportunities, increase productivity, and create green jobs. Furthermore, the environmental-based technologies contribute to improving environmental performance, reducing emissions, and enhancing the overall sustainability of economic activities. Therefore, the significance of technical progress in fostering environmentally sustainable economic growth is shown by the positive correlation between the technology accomplishment index and green growth.

Before concluding, it's worth noting that green growth is contingent on a number of economic variables, such as a country's degree of development, access to technology, and availability of capital. Additionally, social factors such as public attitudes toward the environment and the level of public awareness and engagement, as well as a government's dedication to sustainable development and the existence of enabling rules and regulations are also important political elements that influence green growth. Another determinant is related to technology, which includes the availability of clean technologies as well as the level of innovation and research. Finally, environmental factors must be taken into account. This includes things like the accessibility of natural resources, the incidence of pollution, and other environmental issues. Overall, the success of green growth efforts may depend on a combination of these and other factors, working together to promote sustainable development and protect the environment.

3.4. DISCUSSIONS AND POLICY IMPLICATIONS

This chapter has investigated the empirical relationships regarding the role of the green growth approach in OECD countries. The results presented in this chapter of the thesis, which are based on theoretical and empirical analysis, reveal several significant findings. The outcomes of this chapter rely on both descriptive statistics and regression estimates, revealing the potential parameters that influence the dependent variable in each model. According to the empirical analysis, countries can enhance their environmental conditions through the implementation of low-carbon emission policies, investing in green technologies, and adapting to the impacts of climate change, which can promote green growth and sustainable development. With this respect, the regressions, estimations, and findings described in this chapter seem to ensure significant support for the view that the green growth approach is one of the main factors in promoting low carbon emissions and sustainable development.

Economic performance is the ultimate goal of the interrelated notions of "green growth," "environmental sustainability," and "sustainable development." The progress of sustainable productivity, environmentally-friendly products and technologies, and green policies and laws achieved support environmental sustainability. Additionally, it also involves balancing economic, social, technological, and climatic conditions and environmental objectives and ensuring that development is inclusive and equitable (Fabozzi et al., 2022). One of objective of this study is to explain theoretically the Green Solow model and empirically explore the role of potential macroeconomic factors on green growth in the context of sustainable productivity.

Based on empirical findings, environmental factors including emissions, environmental related tax, and environmental performance index all have a favorable impact on green growth. This finding is consistent with the studies by Biresselioglu et al. (2016), Reilly (2012) and Zhai and An (2021). We find that inequality deteriorates green technology diffusion process in countries. Our findings are compatible with studies by Jha et al. (2018), Kempf and Rossignol (2007), Torras and Boyce (1998), and Vona and Patriarca (2011). Economic factors have a crucial role in promoting both the improvement of green growth. The finding is in line with studies by Chin et al. (2018), Copiello and Grillenzoni (2020), Hussain et al. (2022), Khan et al. (2020) and Samad and Manzoor (2015). Furthermore, socio-economic conditions have a substantial positive impact on green technology diffusion that is also highlighted by Qazlbash et al. (2021). Likewise, institutional factors such as government stability have a positive influence on environmental-based growth, and also democracy in society is a positive and significant determinant of green technology diffusion. Our finding on government stability is compatible with studies by Gao et al. (2017), Koubi et al. (2012) and You et al. (2015). On the other hand, the technology achievement index and general technology diffusion are positive and significant indicators of the progress of green growth. This finding is in line with studies by Adenle et al. (2015), Chen et al. (2018), Shang et al. (2021), Zeng et al. (2020), Zmami and Ben-Salha (2020). Similarly, we draw the conclusion that globalization and green growth advancement are positively correlated. This result is in line with the findings of Bedianashvili (2021), Rahman et al. (2022) and Zafar et al. (2020).

These findings have several important implications for environmental sustainability. Economic growth tends to lead to higher levels of carbon emissions. On the one hand, technological advancements can associate with increased carbon emissions, as industrial processes and transportation methods that rely on fossil fuels emit greenhouse gases. However, advancements in technology have also led to the development of cleaner and more efficient methods of energy production and transportation, such as renewable energy sources and electric vehicles. Hence, it can be inferred that a country has the potential to enhance its green growth index score, even in the presence of high carbon emissions.

In the same vein, a catastrophic effect on climate change adaptation is possible if carbon emissions continue to rise. Due to their greater vulnerability to climate change impacts and their dedication to sustainable development, emerging nations have an especially urgent need for environmentally friendly technology. Some studies have found that green growth is more effective in developing countries than in developed countries, while others have found that green growth can be effective in both types of countries (Huang and Quibria, 2013; Chen et al., 2019; Zecca and Nicolli, 2021). Negative consequences on agriculture, infrastructure, and public health might result from climate change because of the increasing frequency and intensity of natural catastrophes. Countries need to make significant financial investments in measures like sea wall construction, water management system upgrades, and climate-resilient infrastructure development if they are to adapt to the adverse climatic effects. These investments can divert resources away from other areas of economic development, potentially slowing down overall economic growth and hindering progress toward green growth products. However, it is important to note that investing in climate change adaptation measures can also create opportunities for economic performance, particularly in sectors such as renewable energy and sustainable agriculture. Hence, it is possible to achieve climate change adaptation and green growth simultaneously by implementing strategies and innovations that advance environmental sustainability and build resilience against the consequences of climate.

The findings also have implications that globalization facilitates the diffusion and transfer of knowledge, green technologies, and best practices related to environmental sustainability across national borders. For example, the global exchange of ideas and information can lead to the adoption of more sustainable productivity, the development of renewable ecological elements, green technologies, and the implementation of international environmental agreements. Globalization can also create economic opportunities for developing countries, which can lead to increased investment in green technologies and infrastructure. In turn, this drives environmental-based growth and promotes the growth of green industries, creating new jobs and economic performance while also reducing carbon emissions and environmental degradation.

Another important implication presented in this chapter is that there is a negative association between inequality and green technology diffusion. When resources and opportunity aren't shared fairly, it might slow the spread of eco-friendly innovations. In many cases, green technologies require significant upfront investments, which may be difficult for individuals or communities with limited financial resources to afford. Additionally, unequal access to education and training can also hinder the diffusion of green technology. Individuals with less education or training may lack the skills and knowledge necessary to operate or maintain green technologies, making them less likely to adopt them. Furthermore, unequal access to information and supportive policies can also impact the environmental-based technologies.

Overall, the thesis highlights the factors that influence the green growth process. Particularly, the green growth models demonstrate that OECD nations make a contribution thanks to higher growth rates, the spread of green technology, successful adaptation to climate change, large investment in environmentally friendly products, competition and transparency between countries, institutional factors, and environmental performance. In light of empirical results, we emphasize several key elements of green growth progress for policy recommendations. First of all, green growth is a concept that emphasizes sustainable economic development through the adoption of innovative and environmentally-friendly technologies, market-based policies, and a focus on social inclusion. One key aspect of green growth is a focus on innovation and technology development. This involves the development of environmental-based growth that can reduce the use of natural resources and minimize waste and pollution, as well as the improvement of existing technologies. Another aspect of green growth is an emphasis on market-based approaches. Pricing mechanisms, such as carbon taxes, can be used to encourage the use of low-carbon technologies and discourage the use of carbon-intensive technologies. Moreover, green growth acknowledges the value of natural capital and tries to preserve and improve ecological systems like forests, seas, and rich soil in order to fuel economic development. Lastly, green growth promotes social inclusion by ensuring that sustainable economic growth benefits all members of society, including initiatives to reduce poverty and inequality. Consequently, green growth promotes environmental sustainability and sustainable development that benefits both the environment and society.

The findings presented in this chapter have significant implications for green policies on the global agenda. The selection of specific policies will depend on factors such as a country's level of development and environmental concerns. These policies contribute to facilitate the advancement of green growth. One major policy that can make a contribution is carbon emission policies. Greenhouse gas reduction can be incentivized monetarily by the introduction of carbon pricing policies like a carbon tax or cap-and-trade system. It is also crucial to have renewable energy laws in place, such feed-in tariffs or subsidies, which guarantee a stable price for green power. Additionally, an energy efficiency policy is crucial, which may include building codes mandating energy-efficient construction or appliance standards setting minimum efficiency levels for household appliances. Policies related to land use could also be implemented, such as protected areas to conserve natural habitats or zoning laws to promote a compact, walkable environment. Finally, it is crucial to implement policies aimed at reducing waste, which may include programs for recycling or prohibiting specific types of single-use plastics. The selection of policies to promote green growth will ultimately be based on the particular needs and objectives of a given region or country.

There are also many different policies that can support the diffusion of green technology. Firstly, investment in eco-friendly products is encouraged through grants and tax incentives for companies and researchers working on green technology. Innovation policies are essential, such as incubators and accelerators that provide support and resources for startups and other innovative companies working on green technology. Other policies on investment are important, such as venture capital funds and other forms of financing that support the development and deployment of green technology. There should be procurement policies, such as green procurement standards, that require governments and other large organizations to purchase green technology products and services. Lastly, regulation and institutional policies are crucial, such as emissions standards and other environmental regulations that create a market demand for green technology diffusion.

Finally, our findings propose some sustainable environmental policies that may promote the progress of climate change adaptation. Firstly, risk assessment policies should be carried out such as climate impact studies and vulnerability assessments that identify the potential impacts of climate change on different sectors of the economy and society. Planned policies are essential, such as adaptation planning frameworks that outline the steps and resources to be implemented. Infrastructure policies, such as investments in flood control infrastructure, early warning systems, and other adaptation measures, are also important. Furthermore, resource management policies such as improved water management and land use practices can mitigate the effects of climate change on natural habitats and biodiversity. Lastly, disaster response policies are also important, such as emergency preparedness plans and insurance programs that can reduce the costs of natural disasters.

CONCLUSION

A green economy is one that prioritizes people's well-being and social justice while also protecting the environment and conserving scarce natural resources. It encourages eco-friendly behaviors and businesses as a means to long-term prosperity. Establishing a green economy and stimulating green growth calls for substantial adjustments to expenditures in infrastructure, research and development. The UNEP (2011) has created an extensive model aimed at evaluating the possible economic and environmental effects that come with transitioning to a green economy. The UNEP model serves as a valuable framework for comprehending the implications, both in terms of economic and social aspects, as well as the environment, that arises from investing in sustainable practices. From this perspective, green growth is an approach to economic development that aims to achieve sustainable and environmentally friendly growth. It recognizes that conventional models of economic development often harm the environment, resulting in resource depletion, pollution, and other forms of environmental degradation. This is important because green growth encourages countries to achieve their economic goals without damaging the natural resources and ecosystems that are vital for sustaining life on Earth.

Within the scope of green growth, this thesis mainly examines the impacts of economic performance and other key variables of interest on the progress of green growth. The evidence obtained from both the theoretical frameworks and empirical models has shown a number of things worth addressing. The diffusion of green technologies has a positive impact on GDP per capita, income inequality, FDI, socioeconomic conditions, democratic accountability, environmental performance index, general technology diffusion, and the technology achievement index of countries. In contrast, the results indicate that a negative correlation exists between inequality and the spread of green technologies.

Secondly, the thesis investigates the impact of various factors, including economic performance, globalization effect, FDI, environmental and institutional values, technological advancements, climatic conditions, adaptation to climate change and environmental technologies on green growth process. This analysis is conducted by examining cross-country data. The empirical results present those key variables of interest have notable effects on long-run green growth. The evidence suggests that all the factors investigated show a significant contribution to green growth process. We reveal that interaction term of climate change adaptation and CO2 emissions have a negative association with green growth process. Therefore, this finding suggests that the efforts to adapt to climate change may have unintended consequences for green growth, potentially indicating a need for balancing both objectives through sustainable and low-carbon strategies. Climate change adaptation measures may inadvertently lead to increased carbon emissions through indirect mechanisms. For example, building climate-resilient infrastructure may require higher energy consumption during construction, which can contribute to additional carbon emissions. These indirect impacts can offset the positive effects of adaptation measures on green growth.

The results from our empirical estimations have several important implications for environmental sustainability and for green growth strategies and policy design. Firstly, there are various strategies and policies that can be implemented to support the diffusion of green technology. One important implication presented in this chapter is that there is a negative association between inequality and green technology diffusion. Inequitable distribution of resources and opportunity can act as a barrier to the widespread implementation of green technology. Since the implementation of green technology is hampered by the unequal distribution of resources and opportunities, governmental actions are necessary. These interventions should include financial incentives and support, such as tax credits and grants, to make green technologies more affordable and accessible, particularly in disadvantaged communities. Investment in infrastructure improvements, education and awareness programs, and capacity building initiatives are essential to ensure equal access and knowledge about sustainable practices. Additionally, inclusive policy frameworks, public-private partnerships, supportive regulations, and research and development funding can play crucial roles in promoting equity and enabling the widespread adoption of green technologies across diverse communities. By implementing these policies, societies can work towards bridging the gap and creating a more inclusive and sustainable future.

In addition to the aforementioned measures, it is crucial to provide adequate funding and resources to support the research, development, and deployment of green technologies. This includes allocating financial resources towards scientific research, innovation, and technological advancements in the field of sustainable solutions. It is also essential to implement regulations and incentives to encourage the use of green technologies, such as subsidies for the use of clean energy or tax credits for businesses that adopt environmentally friendly practices. By fostering a conducive environment for research and development, societies can accelerate the advancement and adoption of green technologies, thereby driving the transition to a more sustainable future. Next, it is important to promote public awareness and education about green technology and its benefits. Moreover, it encourages the development of infrastructure and supply chains that support the use of green technology, such as through the development of charging infrastructure for electric vehicles or the construction of wind farms. Supporting the development of new business models and financing mechanisms that can help make green technology more widely available and affordable is also important. As the results highlight, the goal of promoting the diffusion of green technology is to accelerate the adoption and widespread use of environmentally friendly and sustainable technologies in order to reduce greenhouse gas emissions, conserve natural resources, and minimize environmental impacts.

Second, there is a diversity of strategies and policies that can promote green development. Promoting the use of clean and renewable energy sources is crucial in reducing the demand for fossil fuels and lowering carbon dioxide emissions. It is important to how effective our advocacy for energy efficiency and conservation is, in the long run, will determine how much progress can be made in lowering energy usage and greenhouse gas emissions. Therefore, spending on R&D to develop and implement environmental-based technologies and adapt to climatic effects may also support to green development.

It is also possible to adopt a variety of tactics and policies to make adaptation to climate change easier. There are several things that may be done to prepare communities for the effects of climate change. Investments in infrastructure and technology are also crucial in assisting communities in adapting to weather changes. Also, supporting communities and individuals in their attempts to adapt to the effects of climate change is crucial, whether via disaster assistance or research and development financing.

As highlighted by the findings, supporting the adoption of behaviors and technology that reduce greenhouse gas emissions is crucial since doing so may slow climate change and make it simpler for communities to adapt to its effects. Restoration of natural systems and the promotion of sustainable land use practices are two examples of ways to strengthen the resilience of communities and ecosystems in the face of climate change. To further aid communities in preparing for and responding to extreme weather events and other repercussions of climate change, it is crucial to develop and implement early warning systems, emergency response plans, and green infrastructure. To this end, it is important to push for the development of insurance and financial systems that can aid communities and businesses in bouncing back from climate change's negative impacts. The overarching goal of these approaches is to lessen the negative impacts of climate change on people and the environment, while also helping communities and ecosystems survive and recover from the consequences of a changing climate.

Supporting the development of green infrastructures is crucial to reducing the demand for individual car use and greenhouse gas emissions in this context. In order to encourage firms to adopt ecologically sustainable practices and limit their environmental impacts, it is vital to implement rules and incentives. In order to lessen the environmental consequences of the agriculture, forestry, and fishing industries, rules and incentives may encourage the use of ecologically friendly goods and methods. To lessen the environmental implications of economic activity, encouraging the adoption of circular economy concepts, which aim to reduce waste and enhance the effective use of resources, is crucial. Incentivize ecologically friendly actions and investments through supporting the development of green markets, such as through the use of carbon pricing or the issuance of green bonds. The objective of these techniques is to promote economic growth while reducing negative environmental consequences and protecting natural resources for future generations.

The theoretical framework presented in this thesis suggests a diffusion process that refers to the spread of new technology or innovation from its point of origin to other places or groups. In the context of green technology, "diffusion" refers to the process by which green technologies are adopted and used by individuals, businesses, and governments around the world. Besides this, the diffusion of green technologies can be influenced by a variety of factors, including the availability and cost of the technology, regulatory policies, cultural and social attitudes, and the level of awareness and understanding of the technology and its benefits. Encouraging the diffusion of green technologies is often seen as a key strategy for promoting sustainable environmental and economic development in areas such as climate change and resource depletion. Another contribution is the derivation of the Green Solow model which is an extension of the standard Solow model of economic growth. As mentioned in Chapter Two, according to the Green Solow model, economic growth is driven by an increase in the stock of capital, the level of technological progress, and the size of the labor force. However, the model also incorporates the negative impacts of environmental degradation on economic growth, which can offset some or all of the benefits of increased capital, technology, and labor.

Before passing on to the final mentions, the analysis presented in this thesis suggests that green growth has major significant determinants. One of the key determinants of the progress of green growth is the income levels of nations. Investing in sustainable technologies, infrastructure, and practices can be costly, and economic development and growth may support implementing green growth initiatives. As highlighted by the analysis, the level of carbon emissions and technological improvement are also significant determinants of the progress of green growth.

Additionally, this thesis concludes by emphasizing the significance of several crucial factors in green growth (Adams, 2009: 55-79). Green growth encompasses several key elements that are essential for its success. It involves preserving and enhancing natural resources and ecosystem services (natural capital), investing in the skills and knowledge of the workforce (human capital), developing sustainable and resource-efficient infrastructure, establishing strong institutional frameworks, fostering innovation through research and development, implementing supportive public policies, and promoting international cooperation. By balancing economic growth, environmental conservation, and social welfare, green growth attempts to create sustainable development. It emphasizes the importance of utilizing natural resources wisely, driving innovation, and working together globally to address environmental challenges and create a more sustainable future.

In summary, green growth refers to a model of economic development that prioritizes sustainability and the protection of the environment. It aims to balance economic growth with the conservation of natural resources and the reduction of negative environmental impacts. More importantly, the effectiveness of policies and regulations is also crucial for promoting green growth. Governments play a central role in establishing the framework for sustainable development and ensuring that businesses and individuals are held accountable for their environmental impacts.

Growing concern for green growth refers to a process of economic development that seeks to increase prosperity and well-being while minimizing negative impacts on the environment. It involves balancing economic, social, and environmental goals and aims to create a sustainable and inclusive economic system. Green growth is likely to become increasingly important in the future as the world faces a number of pressing environmental issues, such as climatic effects, biodiversity loss, and resource depletion. These challenges are likely to have significant economic and social impacts, and addressing them will require a shift towards more sustainable and inclusive forms of economic development.

One key trend in green growth is the increasing role of technology and innovation. As our understanding of environmental impacts and the need for sustainability grows, new technologies and business models are emerging that aim to reduce resource use and environmental impacts. For example, the improvement of environmental and energy technologies, electric vehicles, and circular economy models are all contributing to green growth. In general, there is an increasing awareness of the significance of partnerships and collaboration in fostering green growth. Individuals, corporations, governments, and civil society groups all contribute to the transition to a more sustainable future. Collaboration and the sharing of information and experience may help speed up the shift to a green development economy. In order to encourage businesses and individuals to embrace sustainable practices, governments can also introduce measures such as renewable energy objectives, carbon pricing, and environmental laws and regulations.

Considering the preceding discussions, the advancement of green growth encompasses various initiatives and actions aimed at fostering economic growth while concurrently safeguarding the environment. Firstly, weaning the economy off of fossil fuels and nonrenewable resources is to set renewable energy objectives and encouraging energy efficiency. Secondly, it is necessary to place emphasis on the development of environmental technology in order to expand the use of renewable energy sources and minimize greenhouse gas emissions. Finally, the development and use of cutting-edge technology can be essential in lessening the negative effects of human economic activity on the natural world. Innovations in renewable energy sources, improved manufacturing techniques, and eco-friendly product design all fall under this category. Adopting these policies makes it feasible to promote long-term economic growth while limiting negative environmental impacts (Baker, 2006: 51).

In conclusion, the future of green growth hinges on the integration of technological innovation, policy measures, and collaborative efforts among various sectors and stakeholders. It necessitates a holistic approach that recognizes the interconnectedness of economic, social, and environmental aspects and strives to establish a sustainable and inclusive economic system. Green growth is regarded as the crucial mechanism for harmonizing economic development with environmental considerations and fostering both environmental and economic sustainability that caters to the present and future generations. Ultimately, economic performance and environmental protection can complement each other instead of being at odds, leading to a more balanced and prosperous future for all.

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APPENDICES

APPENDIX 1: List of Countries

Appendix Table 1: List of Countries for Variables in the First Section

Argentina	Australia	Austria	Belgium
Brazil	Bulgaria	Canada	China
Colombia	Croatia	Cyprus	Czechia
Denmark	Egypt	Estonia	Finland
France	Germany	Greece	Hungary
Iceland	India	Ireland	Israel
Italy	Japan	Kazakhstan	Latvia
Liechtenstein	Lithuania	Luxembourg	Mexico
Moldova	Morocco	Netherlands	New Zealand
Norway	Peru	Philippines	Poland
Portugal	Romania	Russia	Saudi Arabia
Serbia	Singapore	Slovakia	Slovenia
South Africa	Spain	Sweden	Switzerland
Thailand	Türkiye	UK	USA
Uruguay	Venezuela		

Appendix Table 2: List of OECD Countries in the Second Section

Australia	Austria	Belgium	Canada
Chile	Costa Rica	Colombia	Czechia
Denmark	Estonia	Finland	France
Germany	Greece	Hungary	Iceland
Ireland	Israel	Italy	Japan
Korea	Latvia	Lithuania	Luxembourg
Mexico	Netherlands	N. Zealand	Norway
Poland	Portugal	Slovakia	Slovenia
Spain	Sweden	Switzerland	Türkiye
UK	USA		

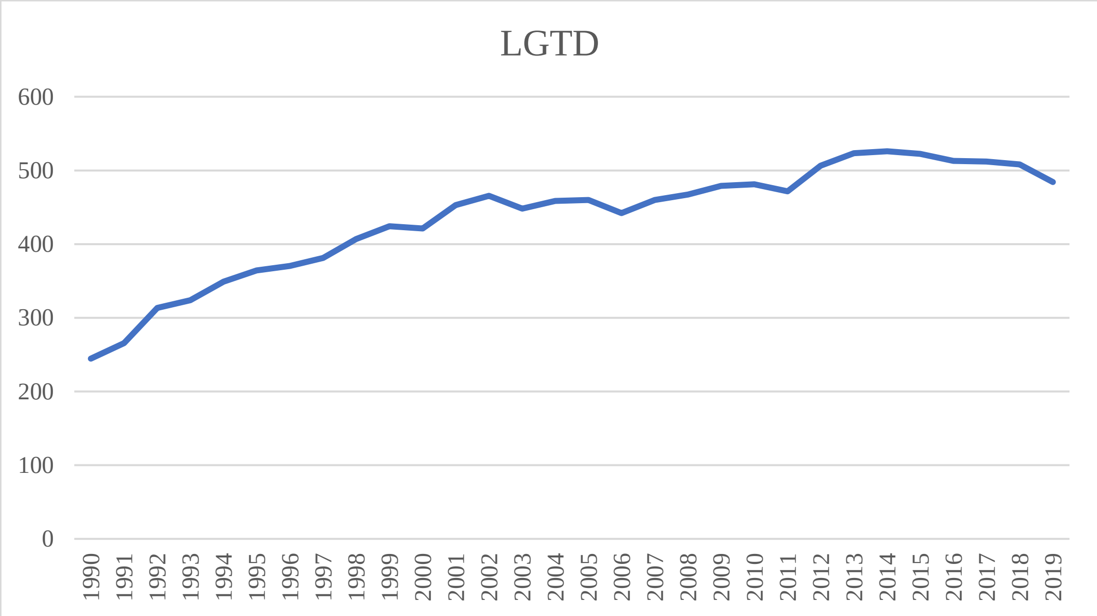
APPENDIX 2: Green Technology Diffusion, General Technology Diffusion, and Technology Achievement Index of Countries by Income Groups Over the Period of 1990-2019

Appendix Table 3: List of Countries by Income Groups, 2021

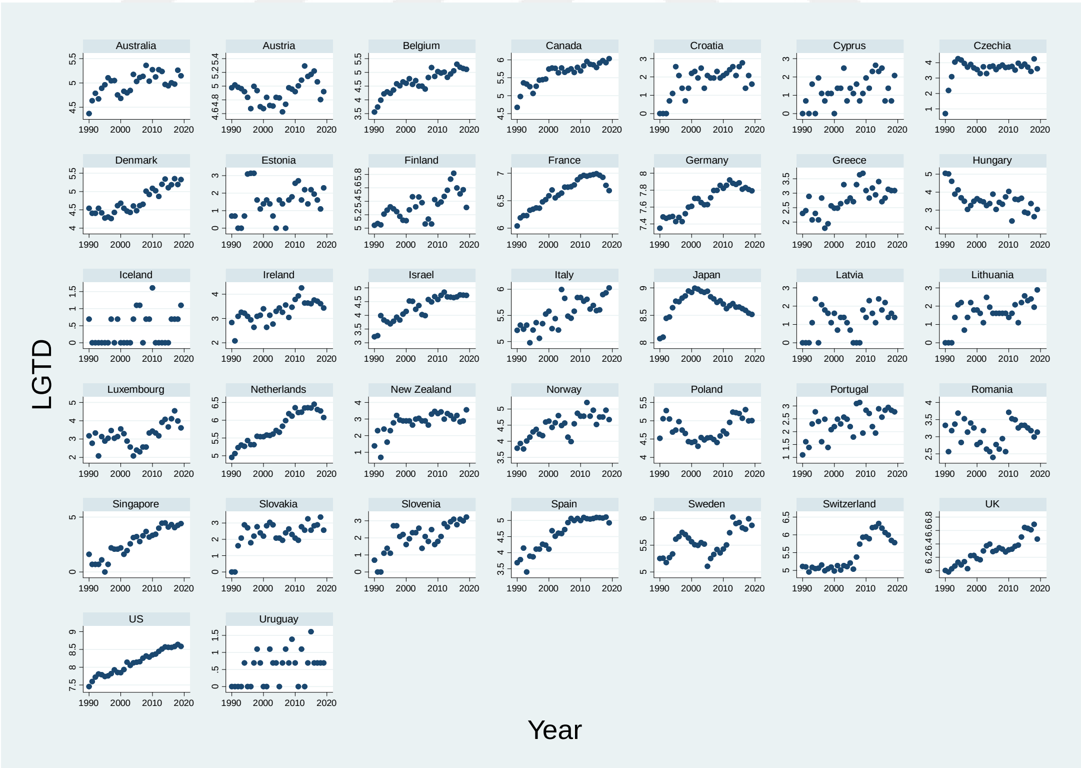
High Income	Upper Middle Income	Lower Middle Income
Australia	Argentina	Egypt
Austria	Belarus	India
Belgium	Brazil	Morocco
Canada	Bulgaria	Philippines
Croatia	China	
Cyprus	Colombia	
Czechia	Kazakhstan	
Denmark	Mexico	
Estonia	Moldova	
Finland	Peru	
France	Russia	
Germany	Saudi Arabia	
Greece	Serbia	
Hungary	South Africa	
Iceland	Thailand	
Ireland	Turkey	
Israel	Venezuela	
Italy		
Japan		
Latvia		
Liechtenstein		
Lithuania		
Luxembourg		
Netherlands		
New Zealand		
Norway		
Poland		
Romania		
Singapore		
Slovakia		
Slovenia		
Spain		
Sweden		
Switzerland		
UK		
Uruguay		
US		

Source: World Bank (2021).

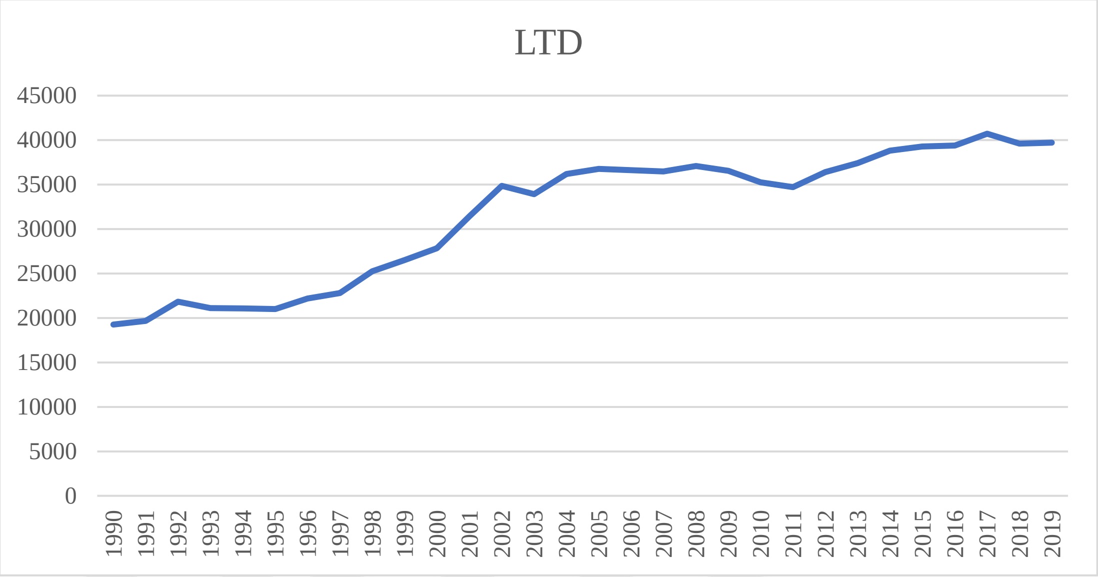
Appendix Figure 1: Green Technology Diffusion in High-Income Level Countries



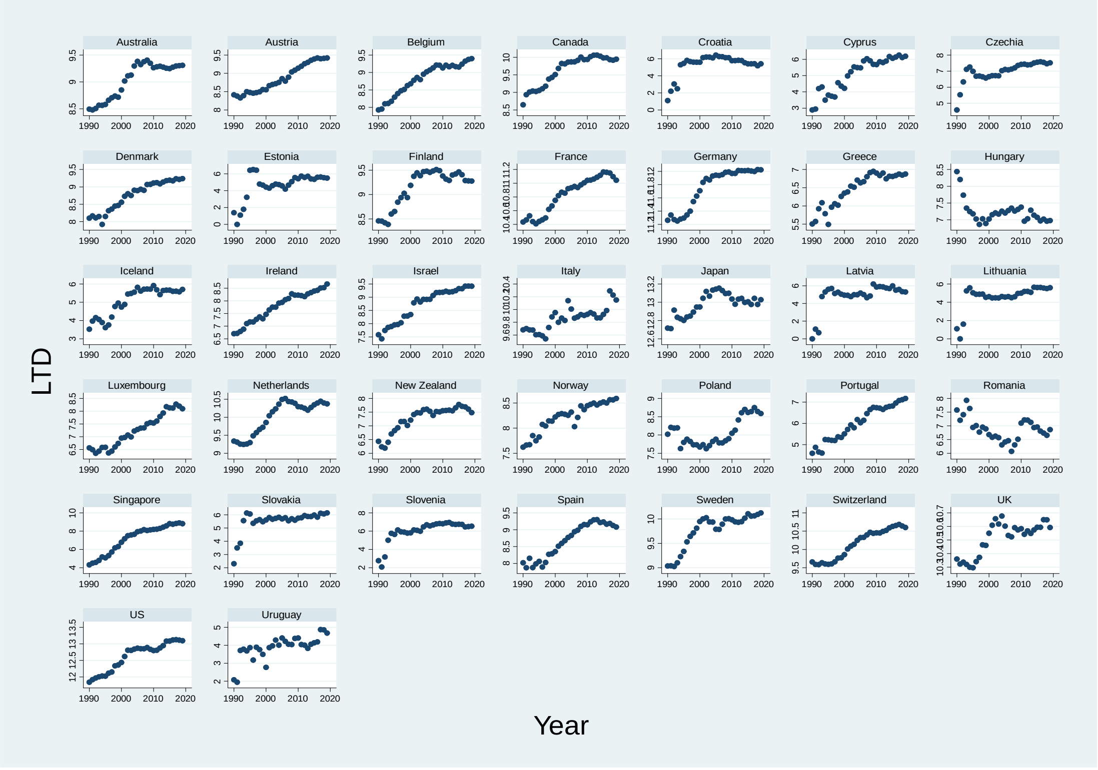
Appendix Figure 2: Scatterplot of Green Technology Diffusion in High-Income Groups at the Country Level



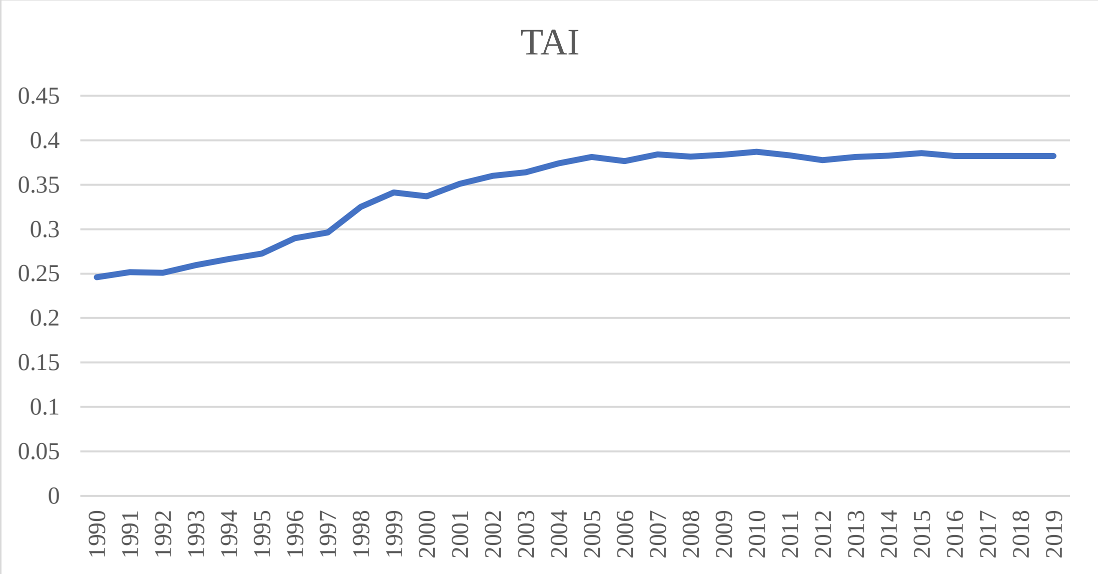
Appendix Figure 3: General Technology Diffusion in High-Income Level Countries



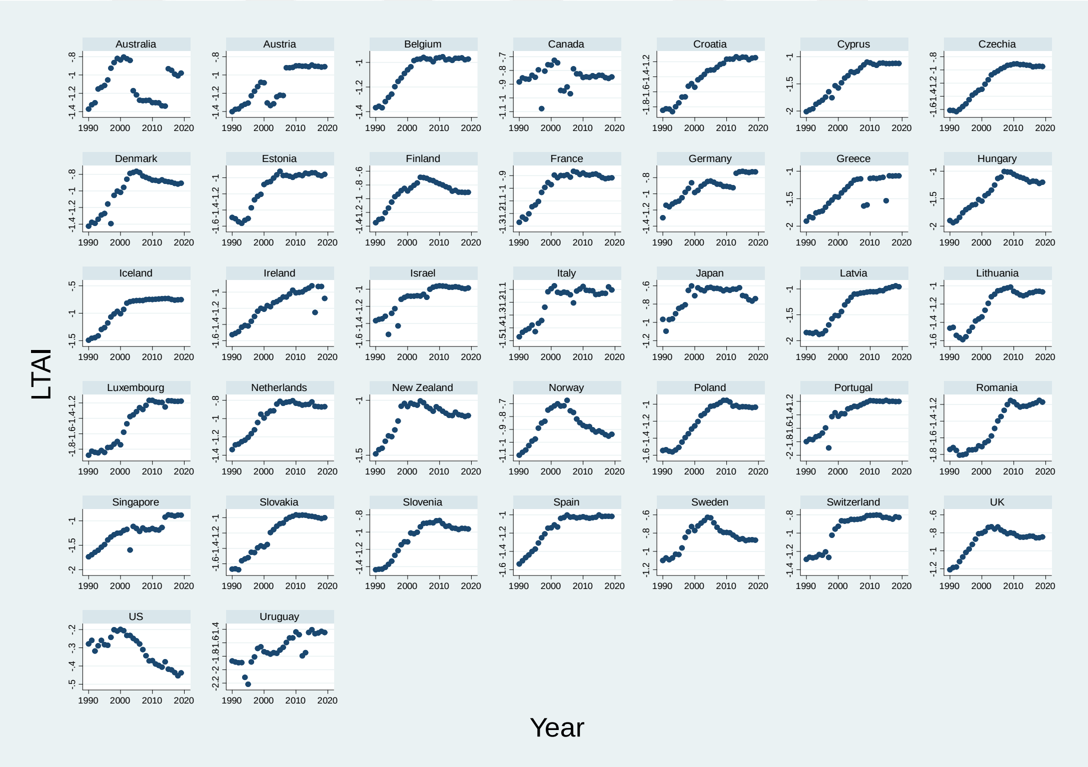
Appendix Figure 4: Scatterplot of General Technology Diffusion in High-Income Groups at the Country Level



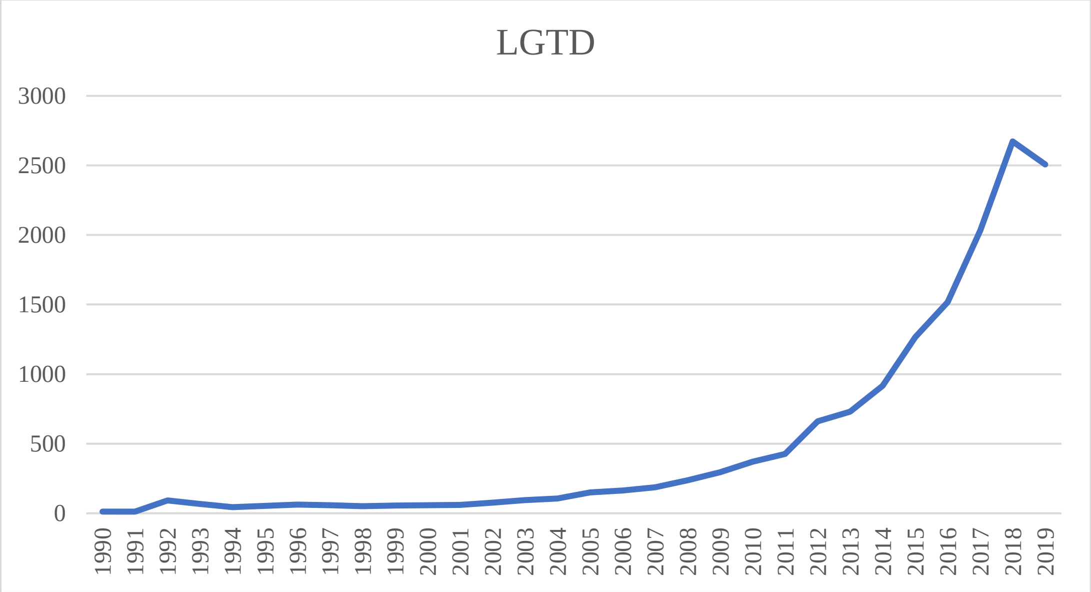
Appendix Figure 5: Technology Achievement Index in High-Income Level Countries



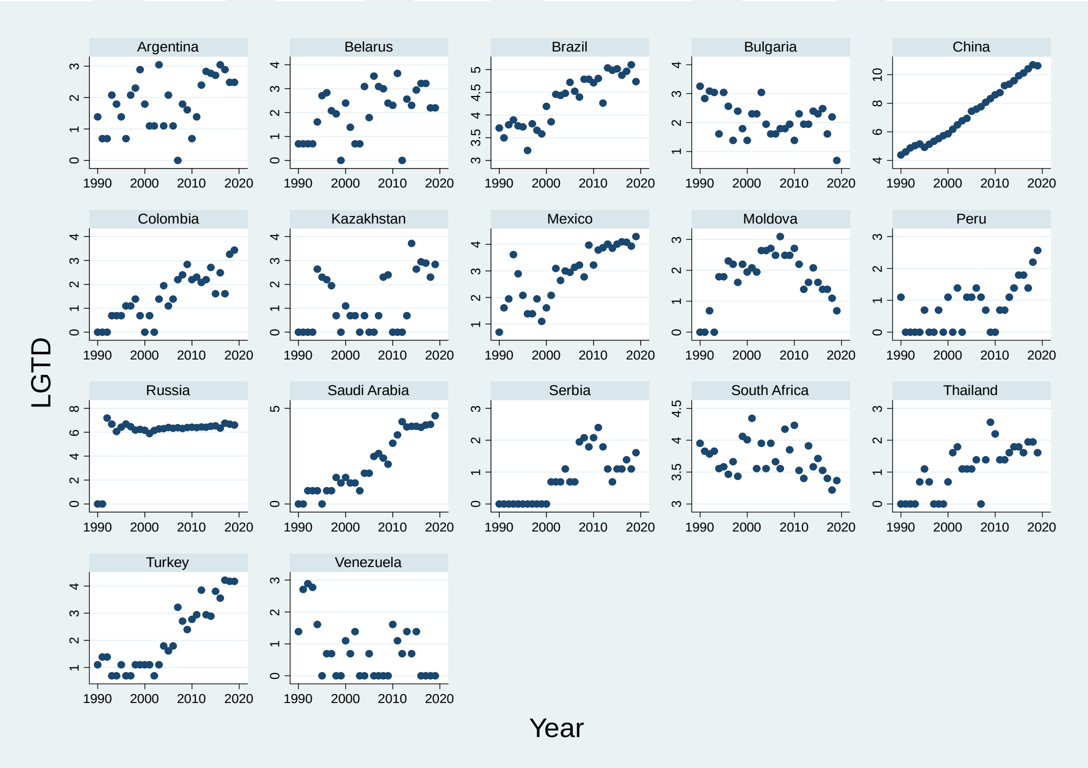
Appendix Figure 6: Scatterplot of Technology Achievement Index in High-Income Groups at the Country Level



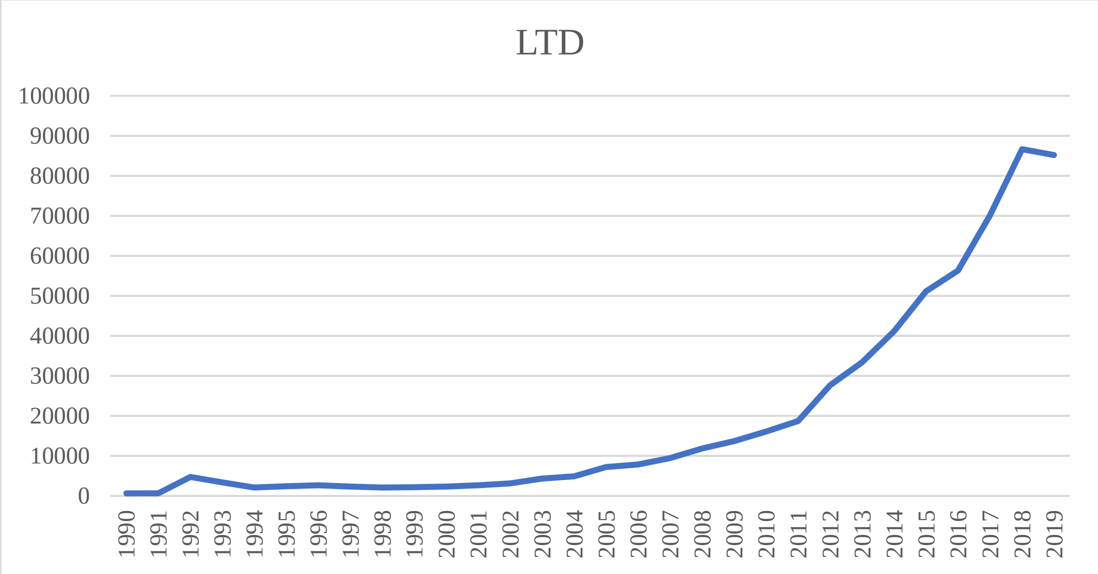
Appendix Figure 7: Green Technology Diffusion in Upper Middle-Income Level Countries



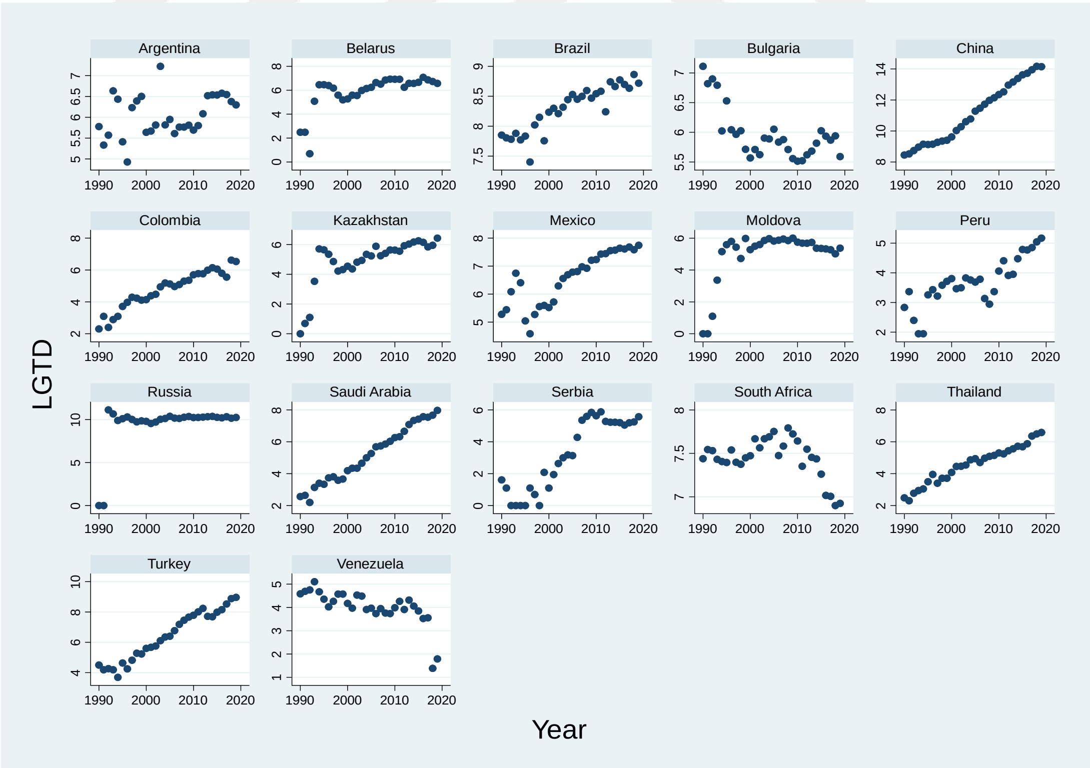
Appendix Figure 8: Scatterplot of Green Technology Diffusion in Upper Middle-Income Groups at the Country Level



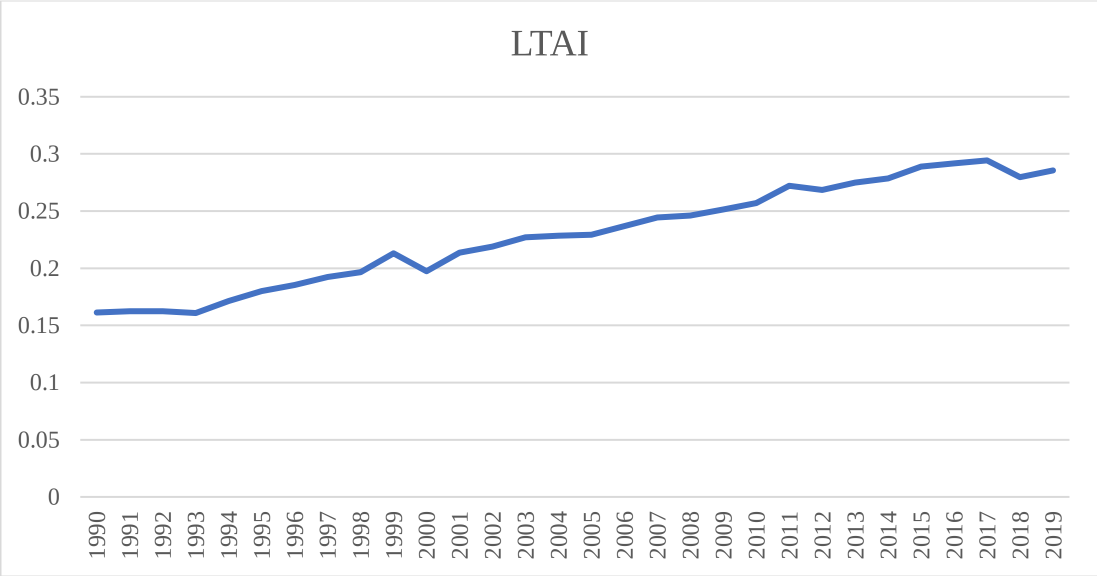
Appendix Figure 9: General Technology Diffusion Index in Upper Middle-Income Level Countries



Appendix Figure 10: Scatterplot of General Technology Diffusion in Upper Middle-Income Groups at the Country Level

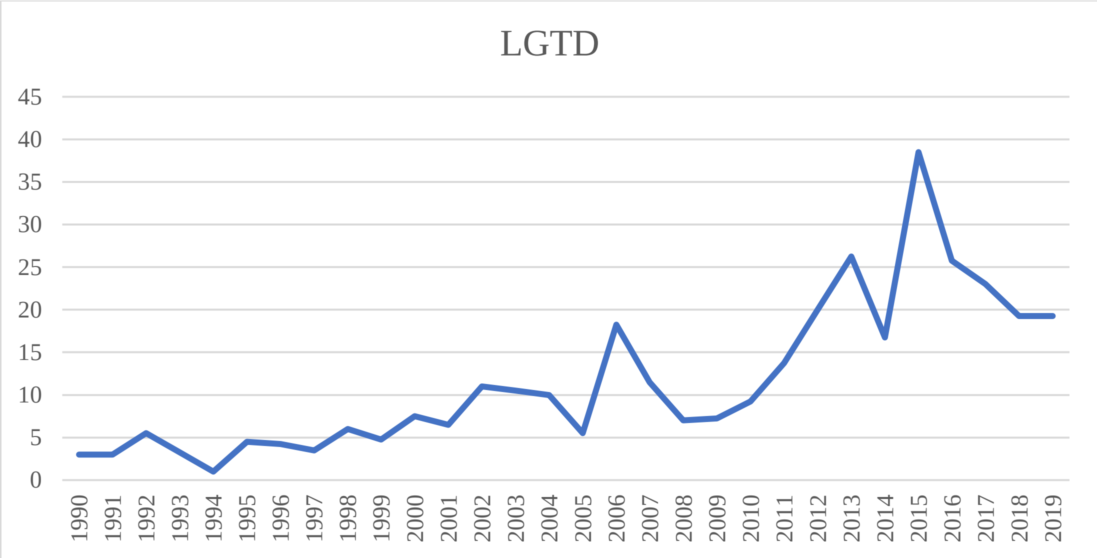


Appendix Figure 11: Technology Achievement Index in Upper Middle-Income Level Countries

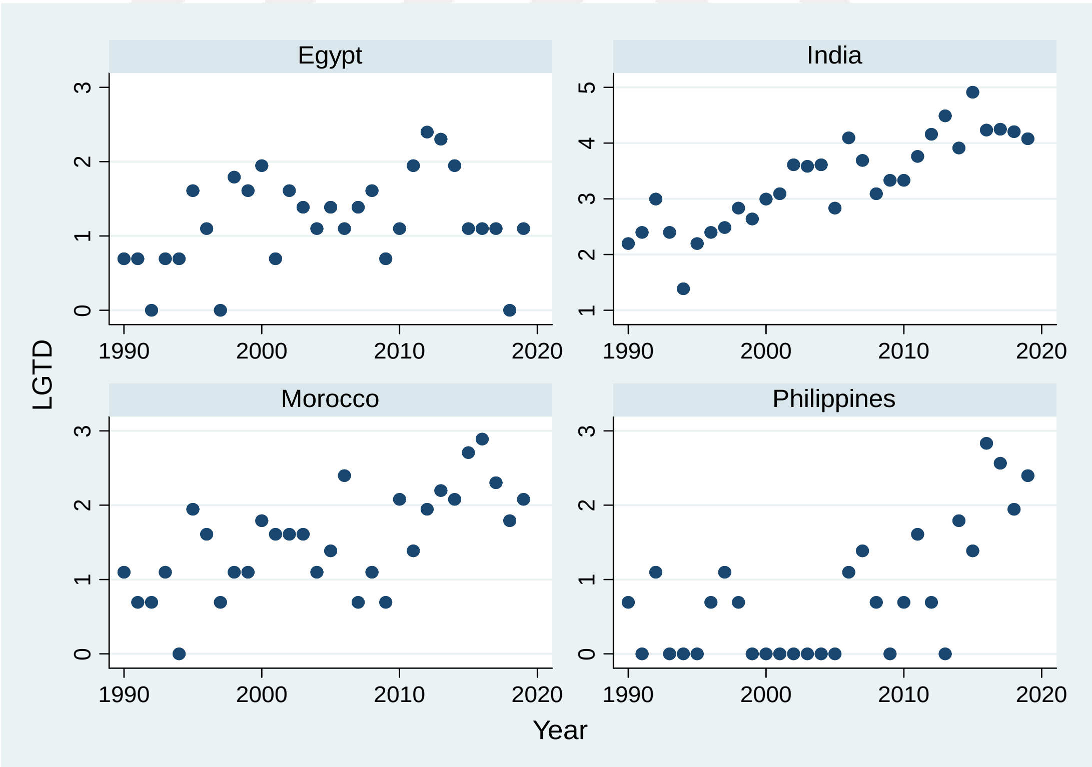


Appendix Figure 12: Scatterplot of Technology Achievement Index in Upper Middle-Income Groups at the Country Level

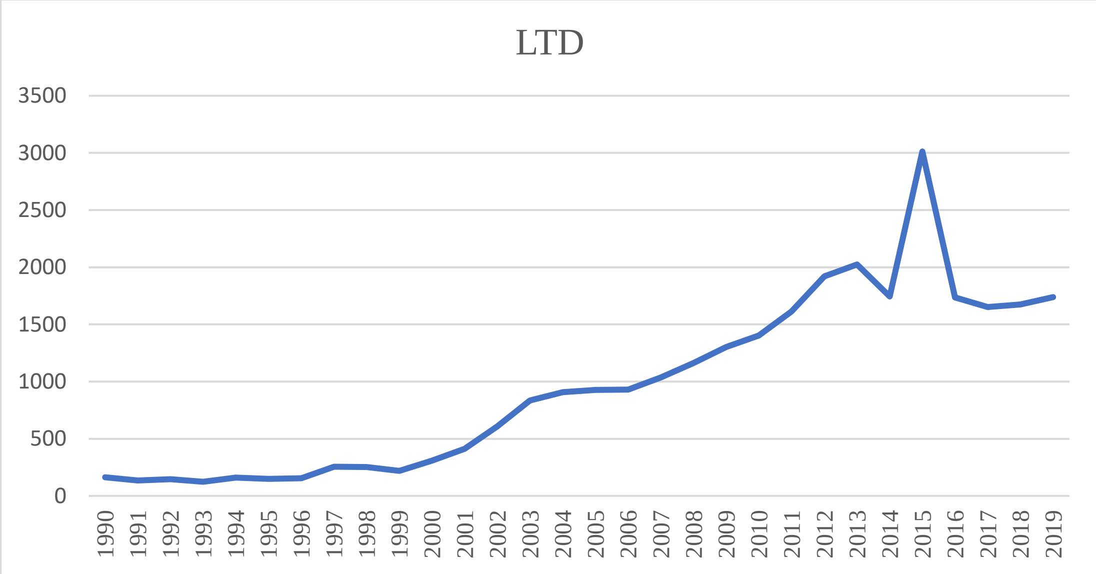
Appendix Figure 13: Green Technology Diffusion in Lower Middle-Income Level Countries



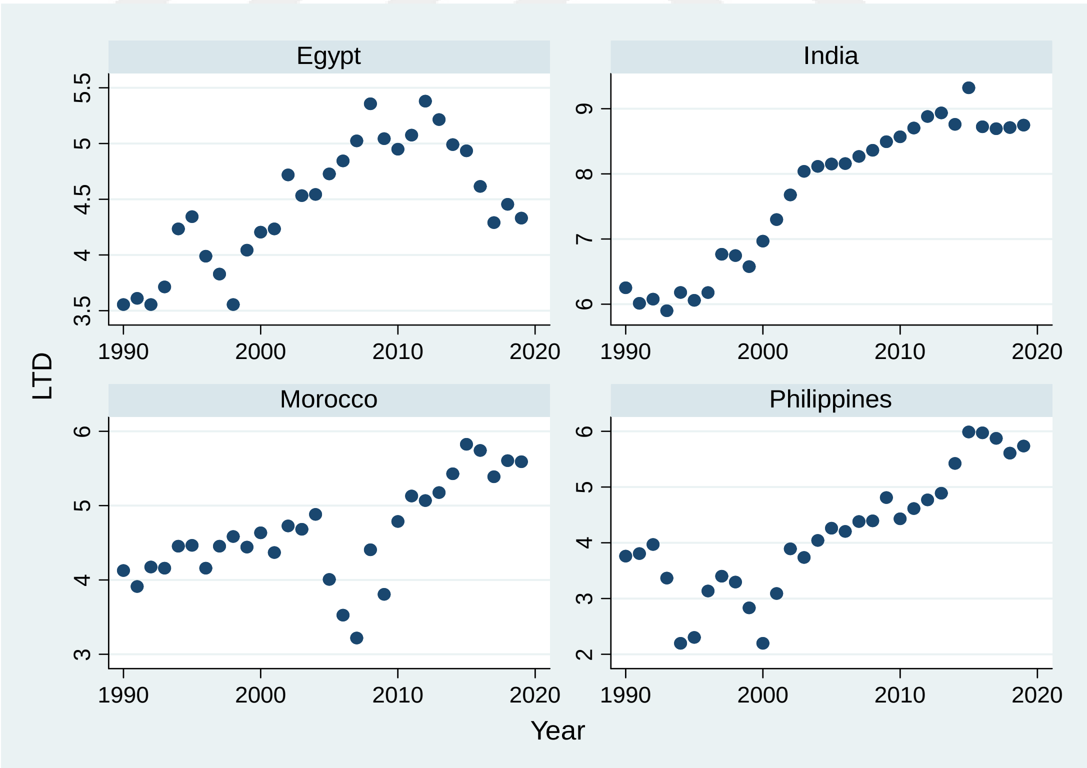
Appendix Figure 14: Scatterplot of Green Technology Diffusion in Lower Middle-Income Groups at the Country Level



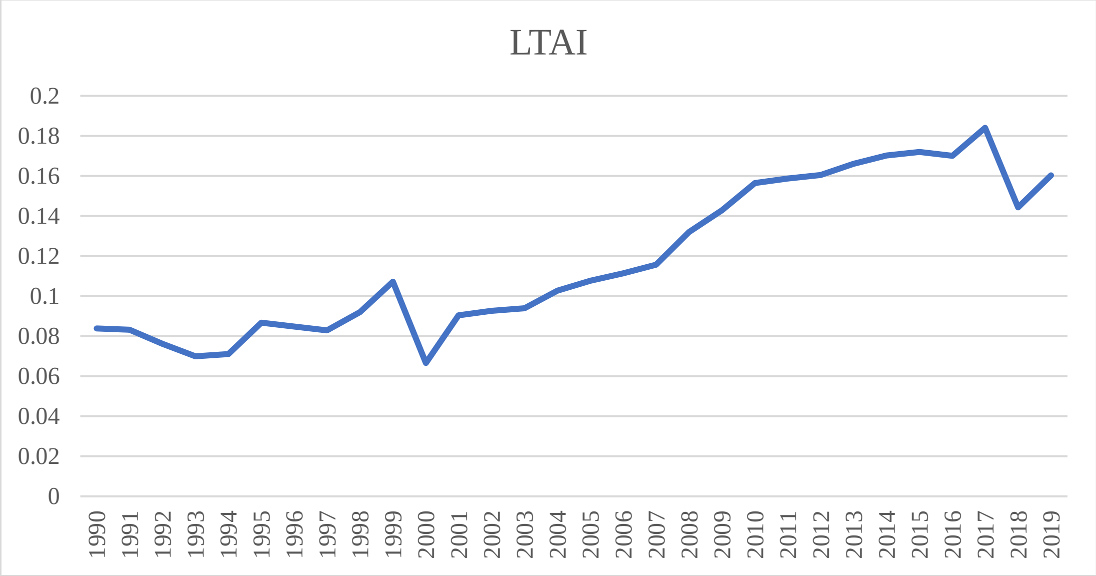
Appendix Figure 15: General Technology Diffusion in Lower Middle-Income Level Countries



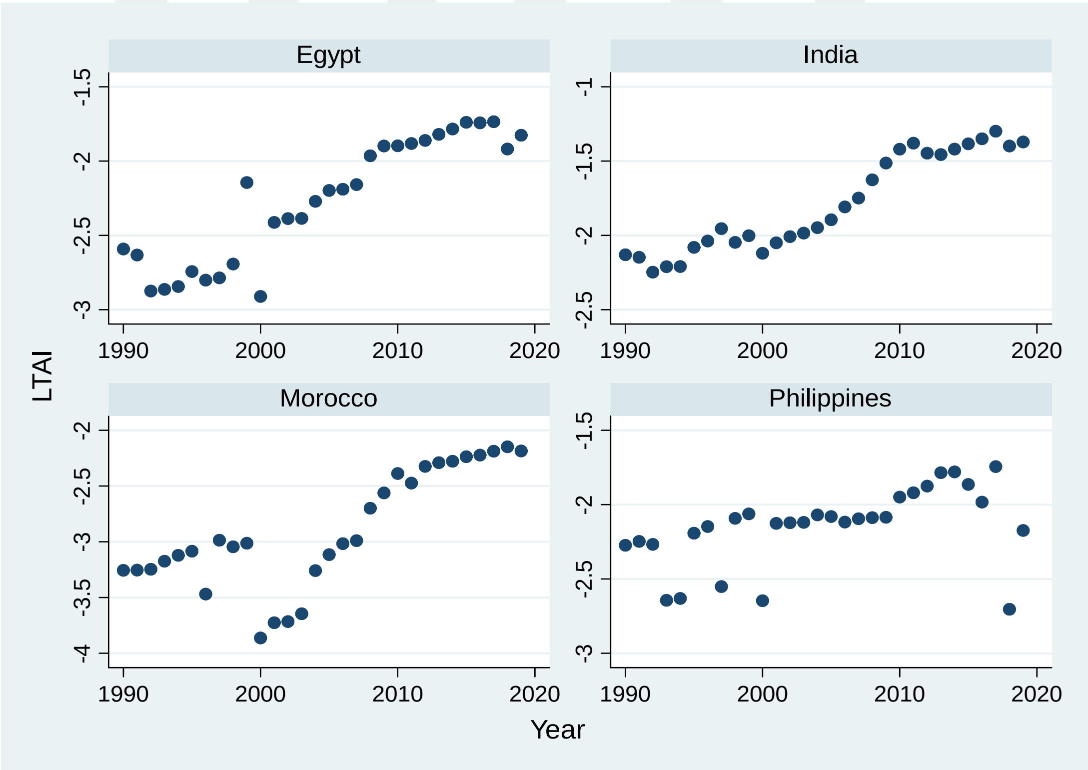
Appendix Figure 16: Scatterplot of General Technology Diffusion in Lower Middle-Income Groups at the Country Level



Appendix Figure 17: Technology Achievement Index in Lower Middle-Income Level Countries

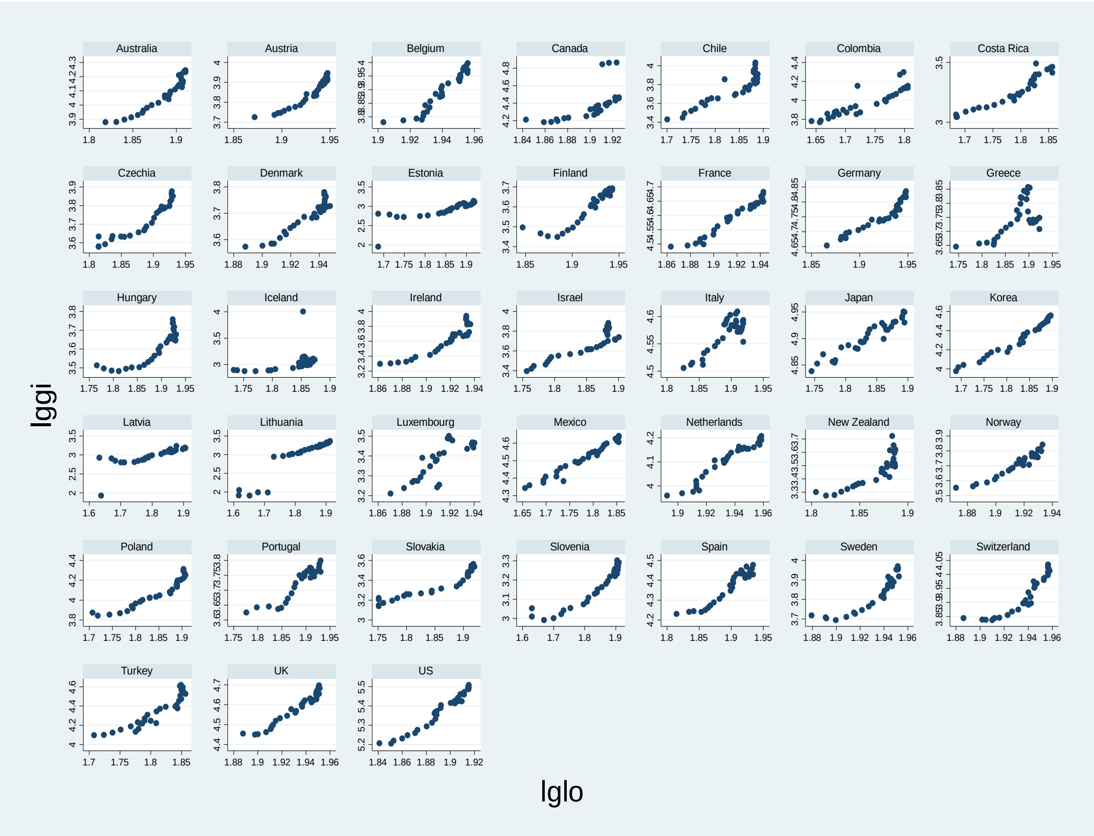


Appendix Figure 18: Scatterplot of Technology Achievement Index in Lower Middle-Income Groups at the Country Level

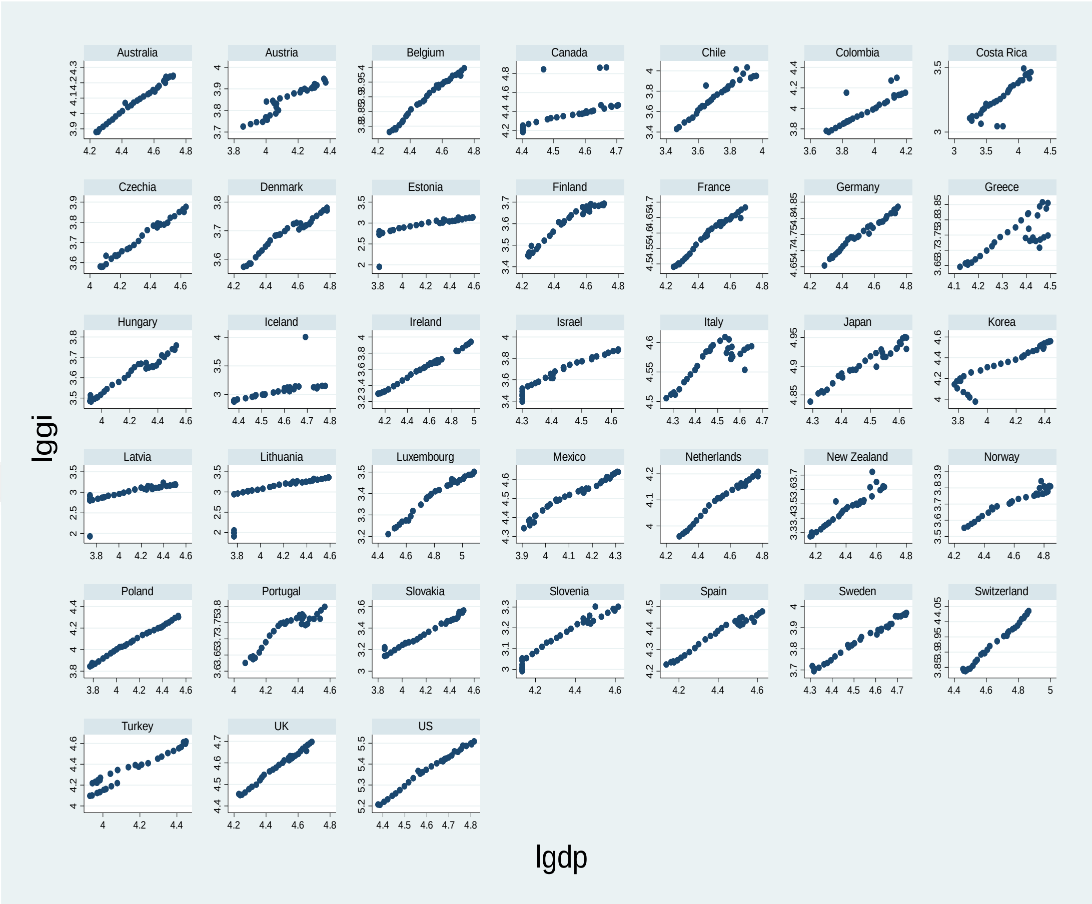


APPENDIX 3: Scatterplots of the Average of Green Growth Index, Globalization, Economic Growth, Green Technology Diffusion, and Climate Change Adaptation by Country Level Over the Period of 1990-2020

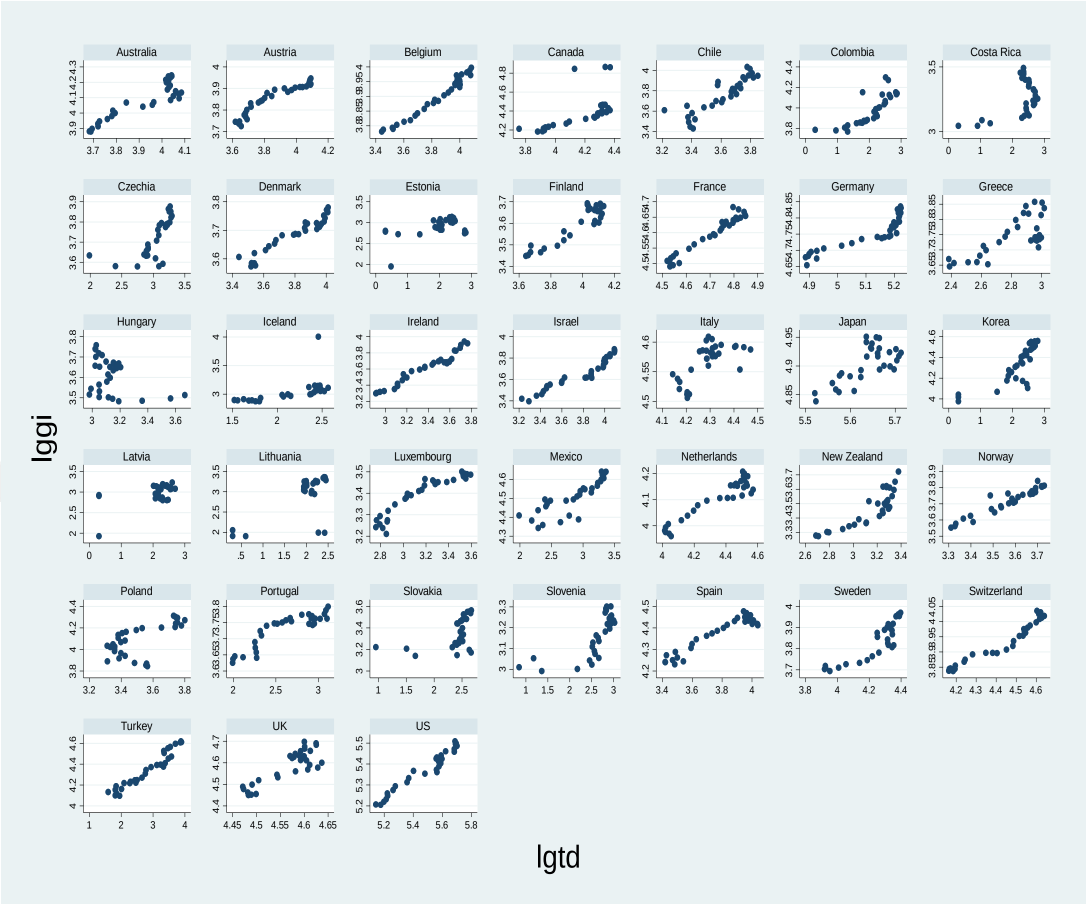
Appendix Figure 19: Scatterplots of Green Growth Index and Globalization by Country Level



Appendix Figure 20: Scatterplots of Green Growth Index and Economic Growth by Country Level



Appendix Figure 21: Scatterplots of Green Growth Index and Green Technology Diffusion by Country Level



Appendix Figure 22: Scatterplots of Green Growth Index and Climate Change Adaptation by Country Level