MEDIATING ROLES OF INDUSTRIAL STRUCTURE AND GREEN TECHNOLOGY IN GREEN FINANCE AND ECONOMIC GROWTH IN DEVELOPED NATIONS

By

DENG WEI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

October 2024

SPE 2024 45

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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October 2024

Chairman : Associate Professor Ridzwana binti Mohd Said, PhD
School : Business and Economics

Globally, rapid economic growth has significantly improved the quality of life for individuals while also leading to significant environmental issues and a depletion of resources. In response to the escalating challenges, countries worldwide are actively transitioning to a novel paradigm of green economic growth. This approach seeks to foster economic expansion while considering limitations on resources and addressing environmental damage. Green finance, industrial structure upgrading, and green technology are all eco-friendly measures for the shift towards green economic growth. Nevertheless, there are conflicting findings on the impact of green finance on green economic growth, and little is known about the mechanisms underlying this impact. Therefore, this study aims to examine the influence of green finance on green economic growth and determine whether industrial structure upgrading and green technology innovation mediate this relationship.

A panel sample of 28 developed countries from 1995 to 2022 is chosen in this research because they have undergone swift economic expansion coupled with substantial pollution, leading to a shift towards green economic growth. Furthermore, this study starts with the measurement of a green economic growth index with a four-dimension and eleven-indicator. Subsequently, this research employs data analysis techniques and various models to examine the impact of green finance on green economic growth and the mediating roles of industrial structure upgrading and green technology innovation.

The findings of this study display that green finance has a positive effect on green economic growth in developed nations. It demonstrates that the transformation of green economic growth could be encouraged through green financial funding for green initiatives. The results also indicate that industrial structure upgrading acts as a positive mediator in the relationship between green finance and green economic growth, contributing to 8.94% of the overall impact. In addition, the enhancing effect of green finance on green economic growth is also strengthened by the mediator of green technology innovation, accounting for 43.52% of the total influence. In conclusion, green finance, industrial structure upgrading, and green technology innovation are key elements in achieving the green economic transformation of wealthy nations. The outcomes of this research contribute to the existing body of literature by proposing a novel theoretical framework for the impact of green finance on green economic growth. Moreover, they provide concrete suggestions for policymakers, especially in developing countries, with concrete measures to achieve green economic growth, such as increasing green financial support for green activities and accelerating the application of green technology innovation. Additionally, investors can derive advantage from these insights to shift their attention towards green projects to optimise asset allocation and long-term investment returns.

Keyword: Green Economic Growth, Green Finance, Green Technology Innovation, Industrial Structure Upgrading

SDG: GOAL 8: Decent Work and Economic Growth

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PERANAN PENGANTARAAN STRUKTUR INDUSTRI DAN TEKNOLOGI HIJAU DALAM KEWANGAN HIJAU DAN PERKEMBANGAN EKONOMI DI NEGARA MAJU

Oleh

DENG WEI

Oktober 2024

Pengerusi : Profesor Madya Ridzwana binti Mohd Said, PhD
Sekolah : Perniagaan dan Ekonomi

Perkembangan ekonomi yang pesat di peringkat global telah membawa peningkatan kualiti hidup yang signifikan kepada individu. Namun, pada masa yang masa, ia telah menyebabkan isu alam sekitar yang signifikan dan ketandusan sumber. Bagi menangani cabaran yang semakin meningkat, negara-negara di seluruh dunia sedang menongkah peralihan ke paradigma baru pertumbuhan ekonomi hijau. Pendekatan ini bertujuan untuk memupuk perkembangan ekonomi sambil mempertimbangkan kekangan sumber dan menangani isu alam sekitar. Sehubungan itu, kewangan hijau, peningkatan struktur perindustrian dan teknologi hijau dilihat sebagai langkah mesra alam dalam peralihan ke arah pertumbuhan ekonomi hijau. Namun begitu, terdapat percanggahan dalam dapatan mengenai kesan kewangan hijau terhadap pertumbuhan ekonomi hijau, dan jurang maklumat mengenai mekanisme yang mendasari kesan ini. Oleh itu, kajian ini bertujuan untuk mengkaji pengaruh kewangan hijau terhadap pertumbuhan ekonomi hijau dan menentukan

peranan pengantara peningkatan struktur industri dan inovasi teknologi hijau dalam hubungan ini.

Sampel panel 28 negara maju dari 1995 hingga 2022 dipilih dalam penyelidikan ini kerana negara-negara ini telah mengalami perkembangan ekonomi yang pantas dan pada yang sama, pencemaran isu pencemaran yang ketara. Ini telah membawa kepada peralihan ke arah pertumbuhan ekonomi hijau. Kajian ini bermula dengan pengukuran indeks pertumbuhan ekonomi hijau merangkumi empat dimensi dan sebelas indikator. Kajian ini menggunakan teknik analisis data dan model yang pelbagai untuk mengkaji kesan kewangan hijau ke atas pertumbuhan ekonomi hijau dan peranan pengantara peningkatan struktur industri dan inovasi teknologi hijau.

Dapatan kajian ini menunjukkan kesan positif kewangan hijau terhadap pertumbuhan ekonomi hijau di negara maju. Ia menunjukkan bahawa transformasi pertumbuhan ekonomi hijau boleh digalakkan melalui pembiayaan kewangan untuk inisiatif hijau. Selain itu, kajian mendapati peningkatan struktur perindustrian mempunyai kesan pengantaraan positif dalam hubungan antara kewangan hijau dan pertumbuhan ekonomi hijau, di mana ia menyumbang kepada 8.94% daripada kesan keseluruhan. Di samping itu, kesan peningkatan kewangan hijau terhadap pertumbuhan ekonomi hijau telah diperkukuh oleh pengantara inovasi teknologi hijau, yang merangkumi 43.52% daripada pengaruh keseluruhan. Kesimpulannya, kewangan hijau, peningkatan struktur perindustrian, dan inovasi teknologi hijau adalah elemen utama dalam mencapai transformasi ekonomi hijau di negara kaya. Hasil kajian ini dapat menyumbang kepada hasil kajian sedia ada dengan mencadangkan rangka kerja teori baharu mengenai kesan kewangan hijau terhadap pertumbuhan ekonomi hijau. Selain itu, ia memaparkan cadangan untuk penggubal dasar, terutamanya di negara membangun untuk memulakan langkah konkrit untuk mencapai pertumbuhan ekonomi hijau, seperti meningkatkan sokongan kewangan hijau untuk aktiviti hijau dan mempercepatkan penerapan inovasi teknologi hijau. Selain itu, kajian dapat membantu pelabur untuk menumpukan perhatian mereka ke arah usaha hijau untuk mengoptimumkan peruntukan aset dan pulangan pelaburan jangka panjang.

Kata kunci: Pertumbuhan Ekonomi Hijau, Kewangan Hijau, Inovasi Teknologi Hijau, Peningkatan Struktur Industri

SDG: MATLAMAT 8: Pekerjaan yang Baik dan Pertumbuhan Ekonomi

ACKNOWLEDGEMENTS

First and foremost, I would like to express my heartfelt gratitude to my supervisor, Dr. Saira binti Kharuddin. Despite her busy schedule, she meticulously guided me through the process of selecting, writing, and revising my thesis. Her constant encouragement pushed me to strive for excellence and to aim for publishing high-quality journal papers. She emphasized the significance of my PhD academic journey, underscoring its long-term benefits after graduation, for which I am deeply thankful.

Secondly, I extend my sincere thanks to my co-supervisor, Dr. Zariyawati Mohd Ashhari. Her constructive feedback on the structure of my dissertation framework, along with her detailed insights and suggestions, proved invaluable in successfully completing my doctoral dissertation. I am profoundly grateful to my supervisory team for their unwavering dedication and hard work, which enabled me to grow immensely during my PhD journey, leaving a lasting and positive impact on my life.

I also appreciate the support of teachers and reviewers for giving me many valuable comments on my thesis.

Lastly, I would also like to thank my parents for their understanding and unconditional support. Their love and the freedom they provided allowed me to embrace and fully experience every stage of life.

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

Saira binti Kharuddin, PhD
Senior Lecturer
School of Business and Economics
Universiti Putra Malaysia
(Chairman)

Zariyawati binti Mohd Ashhari, PhD
Senior Lecturer
School of Business and Economics
Universiti Putra Malaysia
(Member)

ZALILAH MOHD SHARIFF, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 17 April 2025

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LIST OF ABBREVIATIONS

AR	Autoregressive
ASEAN	Association of Southeast Asian Nations
CO2	Carbon Dioxide
FDI	Foreign Direct Investment
FE	Fixed Effect
G7	Group of Seven
G20	Group of Twenty
GDP	Gross Domestic Product
GHG	Greenhouse Gas Emissions
GGKP	Green Growth Knowledge Platform
GMM	Generalised Method of Moments
HT	Harris-Tzavalis
IMF	International Monetary Fund
IV	Instrumental Variable
OECD	Organisation for Economic Co-operation and Development
OLS	Ordinary Least Squares
R&D	Research and Development
RE	Random Effect
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
TW-FE	Two-way Fixed Effect Model
2SLS	Two-step Least-squares Estimator
UK	United Kingdom
VIF	Variance Inflation Factor
WDI	World Development Indicators
WHO	World Health Organisation

CHAPTER 1

INTRODUCTION

1.1 Research Background

The process of industrialisation and urbanisation has facilitated rapid economic growth in both developed and developing countries by enhancing technological progress, increasing labour productivity, and optimising the economic structure (Lin et al., 2017; Turok & McGranahan, 2013). Fig 1.1 illustrates the Gross Domestic Product (GDP) per capita across three categories: developed regions (primarily in Europe and North America), developing regions (notably the Middle East and North Africa), and least developed regions (predominantly in Sub-Saharan Africa). The data spans from 1976 to 2022 and is measured in constant 2015 US dollars. It reveals that there has been a notable rise in GDP per capita across all these regions, with a particularly significant increase observed in developed regions. In addition, Figure 1.2 displays the multiples of GDP per capita growth from 1976 to 2022, offering more clarity on the relative values. It is worth noting from Figure 1.2 that the developing regions exhibit the highest growth rate, exceeding fivefold, followed by the least developed regions with a growth rate of 3.73 times, and the developed regions with a comparatively lower growth rate of 2.15 times.

In general, the GDP per capita has experienced substantial growth globally.

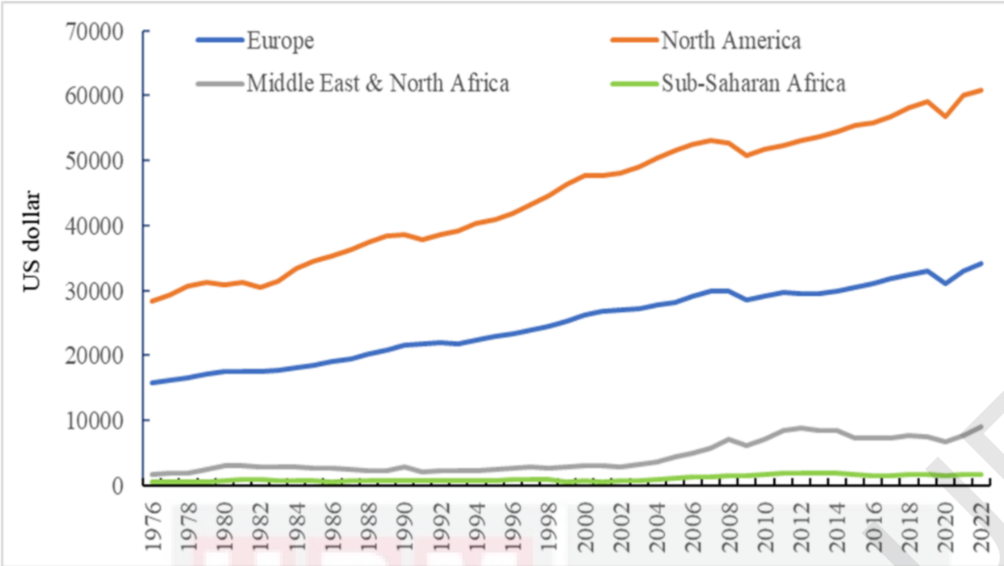

Figure 1.1: Trends in GDP per capita from 1976 to 2022 across developed, developing, and least developed regions
(Source: World Bank)

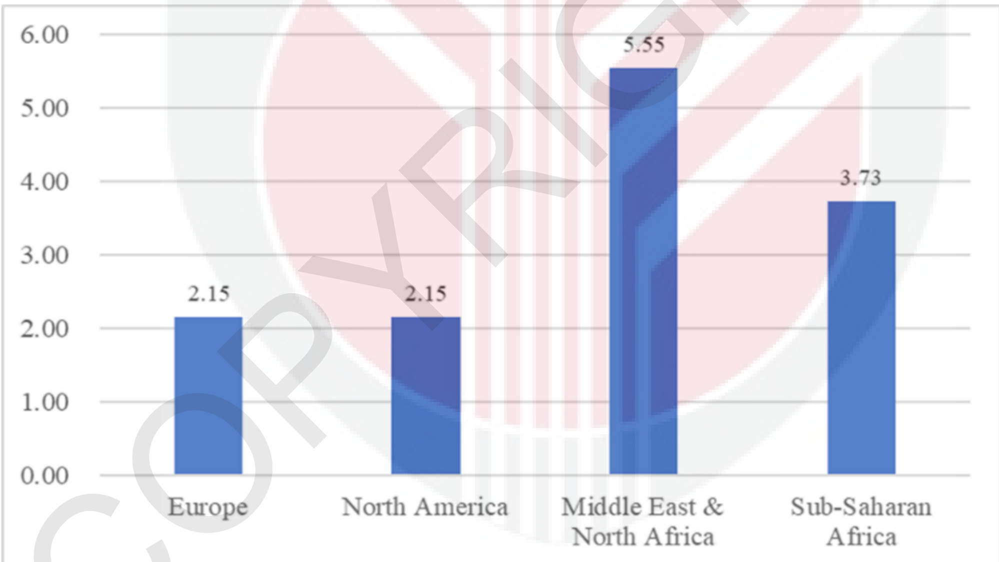

Figure 1.2: Trends in GDP per capita growth multiples from 2005 to 2022 across developed, developing, and least developed regions
(Source: World Bank)

Moreover, industrialisation and economic growth have significantly improved the quality of life for individuals, notably by aiding those living in poverty to overcome their financial hardships. Nevertheless, they also contribute significantly to environmental problems, primarily due to their heavy reliance on fossil fuels. The exponential rise in fossil fuel consumption, driven largely by industrial production, results in significant carbon emissions, which profoundly impact people's livelihoods (Kopidou et al., 2016). In the context of carbon emissions, Figure 1.3 displays the levels of carbon dioxide (CO_2) emissions in developed regions (Europe and North America), developing regions (the Middle East and Asia), and least developed regions (Africa) between 1976 and 2022. The growth tendency in developing and least developed regions is clearly obvious, particularly in Asia, whereas developed regions are seeing a gradual decline but remain at a high level.

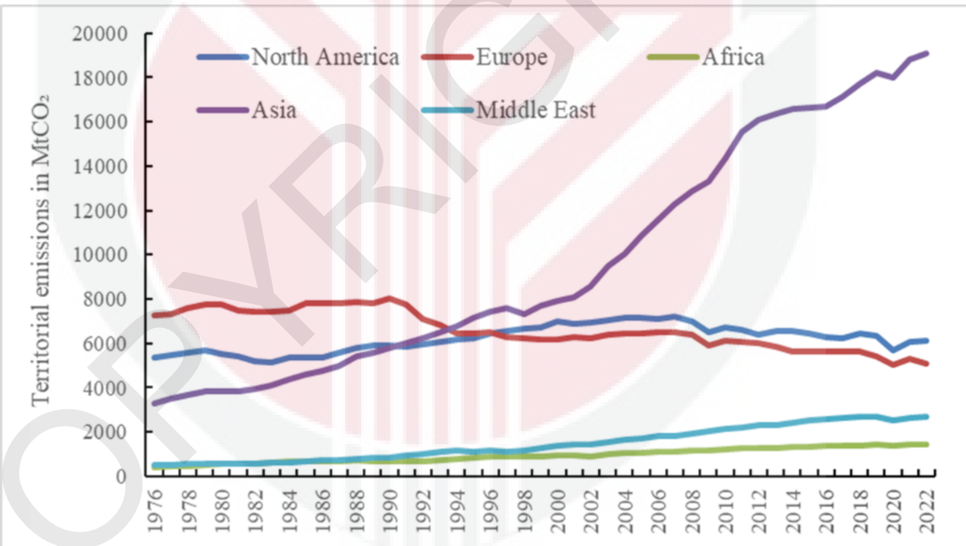

Figure 1.3: Trends in CO_2 emissions from 1976 to 2022 across developed, developing, and least developed regions
(Source: Global Carbon Atlas. http://www.globalcarbonatlas.org

As a result, the significant amount of carbon emissions has caused the greenhouse effect and numerous pollution issues, adversely affecting human health. For instance, greenhouse gases are responsible for approximately

80% of global warming (Liu et al., 2022). Consequently, the continuous increase in CO_2 emissions has a detrimental effect on the human living environment (Mikhaylov et al., 2020). The rising temperature resulting from carbon emissions poses a potential health hazard (Tan et al., 2022) and has also worsened the ozone layer, leading to lower human and ocean life expectancy (Dermawan et al., 2022). Furthermore, the sustainable utilisation of resources is under considerable threat, especially due to the exhaustion of fossil fuels (Adebayo, 2023).

In response to the challenges posed to human society, international organisations have convened with the majority of nations to strengthen collaboration on climate protection, including the Kyoto Protocol (2005), the Paris Agreement (2015), and the 28th Conference of the Parties to the United Nations Framework Convention on Climate Change (2023) (Vyas et al., 2024). Concurrently, governments and organisations are aggressively establishing goals for reducing carbon emissions. For instance, the European Commission aims to achieve net-zero emissions by 2050, with Austria targeting climate neutrality by 2040 and 100% clean electricity by 2030. Similarly, China has committed to reaching carbon neutrality by 2060 and peaking carbon emissions by 2030.

Consequently, to address these serious ecological and resource challenges, countries throughout the world are actively shifting to a new model of green economy. This approach entails fostering economic growth while protecting resources and the environment (Lee & He, 2022). The concept of green economic growth was first introduced in 2005 to explore the development of a model for sustainable development in rapidly growing nations in Asia (Jänicke, 2012). It has sparked widespread concern throughout the world and was seen as an efficient approach to alleviate climate change (Musango et al., 2014). Green economic growth is defined as the realisation of ecological, low-carbon, and circular economic development as the main content, based on the principle of sustainable development with the goal of coordinating economic, social, and environmental development (Zvarych et al., 2023).

In contrast to the traditional economic model that places emphasis on promoting economic growth but results in serious environmental contamination, green economic growth can stimulate economic progress while also safeguarding the environment. It is widely regarded as an effective strategy for reducing carbon emissions, preserving resources, and fostering economic growth (Musango et al., 2014). Furthermore, the green economic growth model, which involves the coordination of the economy, society, and environment, has garnered significant interest from politicians and policymakers as a development paradigm. Governments are progressively embracing this concept and implementing various actions to achieve the shift toward green economic growth (Capasso et al., 2019). In recent decades, governments have made efforts to promote sustainability by implementing legislative and regulatory changes that aim to support green economic growth (I. Khan et al., 2022). These initiatives include green finance, upgrading industrial structures, and promoting innovation in green technology.

In this regard, the financial strategy referred to as "green finance" has gained significant global acceptance and is guaranteed to benefit both the economy and the environment. Green finance is recognised as financial assistance to promote green economic growth, effectively reducing ozone-depleting emissions (Mohd & Kaushal, 2018). Green finance refers to the allocation of funds for green initiatives aimed at fostering a circular economy, including boosting clean energy, lowering greenhouse gas emissions, and supporting other environmental issues (Banga, 2019). Unlike traditional finance, green finance places greater emphasis on environmental considerations, with resource efficiency and environmental protection serving as key measures of success (Zhou et al., 2020). Specifically, green finance distinguishes between eco-friendly and pollution projects through green financial policies and provides funds for green activities of enterprises, ultimately contributing to the shift toward green economic growth.

Thus, the primary aim of green finance is to allocate capital, financing, and operating finances to eco-friendly initiatives that prioritise environmental preservation (Zhou et al., 2020). In this respect, Sharif et al. (2022) have shown that green finance effectively reduces carbon emissions by supporting environmental projects in G7 countries between 1995 and 2019. Additionally, Gu et al. (2023) have found that green finance helps to address the excessive resource consumption in Organisation for Economic Co-operation and Development (OECD) nations. Undeniably, industrialisation in developed countries led to both economic growth and environmental pollution, which prompted these countries to become conscious of the environmental damage and take steps to mitigate it. For instance, in 2007, the European Investment Bank introduced the world's inaugural green bond as a means to assist in the advancement of environmentally friendly initiatives and clean energy (Nguyen et al., 2021).

Furthermore, the process of upgrading the industrial structure is essential for shifting from a rudimentary economic development model to one that robustly supports green economic growth. It is the process of changing a whole industry from a low-level structure to a high-level structure (Song et al., 2021). The transformation is clearly observable in the changing proportions of the primary, secondary, and tertiary sectors on a national scale. As industrial infrastructure improves, the percentage of the primary sector diminishes, leading to a reallocation of resources towards the secondary and tertiary sectors. From a production efficiency standpoint, this transition involves a shift from businesses that rely heavily on manual labour to industries that heavily rely on technology. As a result, there is an increase in production efficiency and the creation of additional value. Industrial structure upgrading involves redistributing resources, such as labour and capital, from places with low efficiency to high-efficiency areas (Gong, 2018). Moreover, the transition of industries from the primary and secondary sectors to the tertiary sector enhances the efficiency of green growth (Zhu et al., 2019). For instance, Xu and Zhou (2023) have demonstrated that in China, the process of upgrading industrial structures promotes sustainable development through both direct effects and spatial spillover effects. Thus, upgrading industrial structures leads to higher added value and reduced pollution. Different industries consume resources at varying levels during economic development; the secondary industry consumes the most and causes the greatest environmental damage, whereas the tertiary industry consumes the least and creates less harm (Jing et al., 2021).

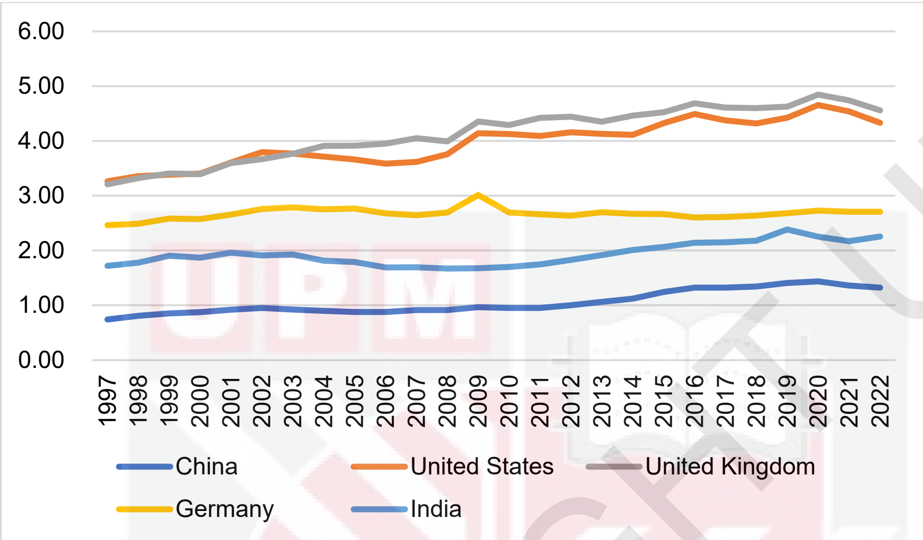

Figure 1.4: Industrial structure upgrading in developed and developing countries from 1997 to 2022
(Source: World bank)

Regarding the upgrading of industrial structures at the national level, Figure 1.4 illustrates the changes that occurred between 1997 and 2022 in both developed and developing countries, as reflected in the ratio of the tertiary to secondary sectors. The countries mentioned, such as the United States, the United Kingdom, Germany, China, and India, encompass both developed and developing economies. In general, developed countries have successfully attained a greater level of industrial structure upgrading, with the United States and the United Kingdom demonstrating consistent patterns. India and China, as representations of developing countries, are both working to improve their industrial infrastructure. However, India has made more substantial progress in this regard compared to China.

Besides, green technology innovation acts as a major stimulant for the advancement of ecological civilisation and green economic growth due to its essential role in energy conservation and environmental protection. Innovation in green technologies encompasses using green energy, equipment upgrades, and process enhancements to conserve energy, mitigate pollution, and optimise production efficiency (Barbieri et al., 2020; Xie & Teo, 2022). This concept involves two primary elements: incorporating resource conservation, ecological protection, and green development into every phase of technological innovation activities and fostering the harmonious interaction between ecology, economy, and resources (Zhuang et al., 2020). Indeed, developed countries have effectively utilised advanced technology to attain superior environmental standards, resulting in a substantial decrease in pollution and enhancement of ecological conditions (F. Wang et al., 2023).

Additionally, green technology innovation has a crucial role in supporting cleaner production and sustainable development (Ikram et al., 2021). It bridges ecological building and economic development by combining environmental conservation and technological innovation (Sun et al., 2022). Undoubtedly, green technology innovation is indeed a variety of environmental technology that aims to achieve the sustained growth of the economy as well as the environment.

Based on the above-mentioned discussion, green finance, industrial structure upgrading, and green technology innovation all contribute greatly to environmental protection and green economic growth. Moreover, there have been studies examining the relationship between these component variables. For example, Nur Utomo et al. (2020) argue that green finance facilitates the advancement of industrial structure upgrading in Indonesia by employing several methodologies, including green bonds and green loans. In order to successfully transition to renewable energy and promote green economic growth, the utilisation of green finance is employed to finance the invention of green technologies (Madaleno et al., 2022). Hence, the combined impact of these influencing elements may contribute to the attainment of green economic growth. Specifically, green technology innovation and upgrading industrial structures may be crucial factors in the relationship between green finance and green economic growth. These factors can be explained as follows:

Implementing reasonable environmental regulations can serve as an indication that the allocation of resources is not efficient and that there is a need for technological advancements. This, in turn, can independently stimulate the "innovation compensation" effect, ultimately leading to both environmental and economic benefits through enhanced production (Porter & Van der Linde, 1995). Green finance is an innovative and expanded form of traditional environmental law in the financial sector. It can be seen as a distinct form of environmental regulation (Su et al., 2022). As a result, green finance can incentivise businesses to foster advancements in green technology by providing financial assistance. Companies that enhance production efficiency and utilise clean energy considerably contribute to green economic growth through the improvement of green technology innovation. In other words, green technology innovation may positively mediate the relationship between green finance and green economic growth.

Moreover, green finance offers financial assistance to environmentally friendly sectors and imposes green financial rules to limit the activities of polluting industries, thereby encouraging the improvement of industrial structure. Responsible environmental management and preservation are core goals of green finance, which can efficiently divert funds from polluting sectors to eco-friendly sectors (Lv et al., 2021). The process of upgrading industrial structures results in a decrease in industries that cause pollution and growth in environmentally friendly sectors, especially in the tertiary sector, which has the highest economic value and the least amount of pollution. This transformation ultimately contributes to green economic growth. The primary factor influencing the reduction of carbon emissions is the industrial structure transformation from heavy industries to technology and service industries (Green & Stern, 2017). Hence, industrial structure upgrading might positively mediate green finance's impact on green economic growth. Thus, the objective of this study is to examine the impact of green finance on green economic growth and determine whether green technology innovation and industrial structure upgrading mediate the relationship between green finance and green economic growth.

1.2 Problem Statement

The persistent increase in CO_2 emissions exerts a harmful impact on human living conditions, exacerbating climate change and the greenhouse effect. Furthermore, the sustainable utilisation of resources is much at risk, particularly due to the exhaustion of fossil fuels (Adebayo, 2023). In response to the challenges posed to human society, international organisations have convened with the majority of nations to strengthen collaboration on climate protection, including the Kyoto Protocol (2005) and the Paris Agreement (2015). Concurrently, governments and organisations are aggressively establishing goals for reducing carbon emissions. For instance, the European Commission aims to achieve net-zero emissions by 2050. Similarly, China has committed to reaching carbon neutrality by 2060 and peaking carbon emissions by 2030. In order to address climate challenges and accomplish environmental targets, countries around the world are actively shifting from crude economic growth to green economic growth models. Nevertheless, this transition to green economic growth cannot happen spontaneously or exclusively through market mechanisms. This critical issue requires comprehensive investigation and effective remedies to ensure the accelerated realisation of the green economy transition.

To address the challenges posed by rising CO_2 levels and climate change, green finance is critical for the preservation of environmental sustainability. This approach has been widely embraced on a global scale. In comparison to conventional finance, green finance places greater emphasis on environmental issues and considers resource efficiency and environmental conservation as essential indicators for evaluating the effectiveness of its initiatives (Zhou et al., 2020). Moreover, green finance fosters green economic growth in Belt and Road Initiative member countries as well as in G20 economies (Ma et al., 2023). However, some scholars present differing perspectives. For example, green finance facilitates carbon emission intensity in China through structural transformation (Gan & Voda, 2023), which is detrimental to green economic growth. Besides, research suggests a U-shaped relationship between green finance and green economic growth in Chinese provinces (J. Zhang et al., 2022). These conflicting findings reveal a gap in the literature regarding the impact of green finance on green economic growth. Therefore, it is crucial to conduct a more in-depth analysis of this issue to determine the impact of green finance on green economic growth.

Furthermore, understanding the impact of green finance on green economic growth could provide insight into how green finance affects green economic growth. This is essential to effectively achieving the goals. Previous research mainly emphasises the engines of green economic growth, such as environmental regulation, financial support, technology innovation, and industrial structure (Su & Fan, 2022a). Nevertheless, there are limited studies investigating the impact mechanism in the link between green finance and green economic growth, particularly without forming a well-developed research framework. Hence, this study concentrates on investigating these issues using pertinent empirical evidence and supported theories.

On the one hand, industrial structure upgrading promotes green economic growth through increased added value and reduced pollution. More importantly, it may mediate the impact of green finance on green economic growth. From the perspective of literature, green finance enhances the upgrading of industrial structures in China by supplying the required funding (Zhang, 2023). Meanwhile, industrial structure upgrading has been proven to facilitate green economic growth in South Asia (Fang et al., 2022) and China (Xu & Zhou, 2023). Theoretically, green finance leads to the decrease in primary and secondary industries (high consumption and pollution) and the increase in the tertiary sector (lowest pollution and highest added value) through green financial policy. According to the Industrial Diffusion Theory, the upgrading of industrial structures in turn improves green economic growth due to environmental and economic benefits. Hence, industrial structure upgrading could further facilitate the promotion effect of green finance on green economic growth. Besides, prior research has shown that industrial structure upgrading plays a mediating role in the relationship between technological change and the forestry economy (Jiang & Wang, 2022). Nevertheless, no studies have regarded it as a mediator in the link between green finance and green economic growth. Therefore, more research is required for this question to explore the mediating effect of industrial structure upgrading on the impact of green finance on green economic growth.

On the other hand, the impact of green finance on green economic growth might also be strengthened by the mediator of green technology innovation. From the empirical findings, green finance stimulates green innovation of enterprises in both developed and developing nations by substantially alleviating financial constraints (H. Huang et al., 2022). Meanwhile, green innovation contributes to green economic growth by aligning economic growth with environmental preservation (Ikram et al., 2021). Theoretically, green finance provides financial support for enterprises' green activity, such as green innovation. According to the Porter Hypothesis Theory, the improved green innovation of enterprises would accelerate clean energy usage, benefitting the environment. Hence, green technology innovation potentially reinforces the contribution of green finance to green economic growth. Additionally, a previous study has demonstrated that green technology innovation positively mediates the link between digitalisation and the growth of the green economy (Hao et al., 2023). However, there is a lack of extensive study regarding green technology innovation as a mediator on the impact of green financing on green economic growth. Therefore, further investigation into the issue is necessary to examine the role of green technology innovation in mediating the connection between green finance and green economic growth.

In order to address those knowledge gaps, this study aims to examine the influence of green finance on green economic growth as well as the mediation effects of industrial structure upgrading and green technology innovation. This will serve as the foundation for the creation of green finance policy as well as other measures aimed at achieving green economic growth.

1.3 Research Questions

Based on the problem statement discussed above, this research seeks to answer the following questions:

i. What is the impact of green finance on green economic growth?
ii. What is the role of industrial structure upgrading in mediating the relationship between green finance and green economic growth?
iii. What is the role of green technology innovation in mediating the relationship between green finance and green economic growth?

1.4 Research Objectives

This study aims to explore the impact of green finance on green economic growth and whether upgrading industrial structures and implementing green technology innovation mediate this impact. Therefore, this study has developed the specific objectives based on the problem statement and research questions.

i. To investigate the relationship between green finance and green economic growth.
ii. To examine the mediating role of industrial structure upgrading in the relationship between green finance and green economic growth.
iii. To examine the mediating role of green technology innovation in the between green finance and green economic growth.

1.5 Significance of the Study

This research substantially advances the fields of theory and practice by conducting a comprehensive analysis of how green finance can stimulate green economic growth. This is achieved through the intermediary effects of upgrading industrial structures and fostering innovation in green technology. This dual contribution provides a strong basis for future research and practical approaches targeted at attaining sustainable development. The following sections provide a detailed discussion of its theoretical and practical significance.

1.5.1 Theoretical Significance

(1) This study provides significant contributions to the current body of knowledge by constructing a thorough theoretical framework that clarifies the influence of green finance on green economic growth. There is disagreement among academics regarding the relationship between green finance and green economic growth; some argue for a positive impact (Ma et al., 2023; Zhang et al., 2021), while others argue for a negative or different impact (Gan & Voda, 2023; J. Zhang et al., 2022). Hence, this study further investigates the influence of green finance on green economic growth.

Furthermore, prior studies have mainly focused on the factors that contribute to green economic growth, such as financial assistance, technological advancements, and industrial structure (Su & Fan, 2022b; L. Wang et al., 2022; Yang et al., 2021; G. Zhou et al., 2022). Nevertheless, there are limited studies investigating the impact mechanism in the link between green finance and green economic growth. Specifically, the existing studies have not explored the mediating effects of industrial structure upgrading and green technology innovation in the link between green finance and green economic growth. In order to fill these gaps, this study combines the principles of the Green Finance Theory, the Industrial Diffusion Theory, and the Porter Hypothesis Theory to provide a comprehensive framework that elucidates the ways in which green finance promotes green economic growth. By highlighting both direct and mediating effects, this dual approach offers a more comprehensive understanding of the mechanisms behind how green financing affects green economic growth.

(2) This study develops a novel and comprehensive index of green economic growth by employing the entropy-weighted TOPSIS approach. Specifically, this index introduces a new indicator of female workforce participation. First, this research addresses the absence of a universally recognised index system for assessing green economic growth by establishing a novel index system with four dimensions and eleven indicators. Second, the entropy-weighted TOPSIS approach is used to measure this composite index of green economic growth in sample countries. This method integrates the advantages of both the entropy and TOPSIS approaches to enhance the scientific evaluation process and results. It uses the entropy method to determine the weights of the indicators and then employs the TOPSIS method for the final decision-making evaluation. Hence, this approach offers a more objective and reliable evaluation compared to alternative techniques, such as single-index or production efficiency methods.

(3) A new perspective of industrial structure upgrading and green technology innovation helps to understand how green finance affects green economic growth. From the perspective of green technology innovation, the green innovation of enterprises could be effectively incentivised by green finance with target funds, which will improve enterprises' production efficiency as well as pollution reduction, supporting the achievement of green economic growth. In terms of industrial structure upgrading, green finance guides financial resources away from the primary and secondary industries towards the tertiary sector with the highest added value and lowest pollution, leading to the upgrading of industrial structures. And a reduction in the polluting industry and

an increase in the tertiary industry will make a great contribution to green economic growth.

1.5.2 Practical Significance

This study provides useful insights for policymakers, companies, and investors, illustrating the significance of green finance in facilitating the improvement of green economic growth. These findings establish a solid basis for the development of policies that are designed to promote green economic growth.

(1) Policymakers can leverage these insights to design effective green finance, industrial structure upgrading, and green technology innovation policies that support a green economy. Specifically, the study recommends that governments monitor and evaluate regional development using the green economic growth index and formulate targeted policy frameworks accordingly. For instance, governments can use the green economic growth index as a benchmark for gauging regional and national performance in green development. This enables the evaluation of whether economic activities are sustainable and environmentally friendly. Policymakers can develop strategies to ensure that economic development does not surpass the endurance of the environment and resources, thus mitigating negative impacts on the environment and human survival. By proposing policies based on empirical research, this study helps countries, especially developing ones, design comprehensive policy frameworks to achieve green economic growth.

(2) The study emphasises the strategic significance of allocating resources to green technologies and implementing sustainable practices within firms, as these measures can improve operational efficiency and mitigate ecological harm. Businesses should acknowledge the intermediary function of green technology innovation in the connection between green finance and green economic growth. Investments in green technologies can enhance sustainable competitiveness and foster green economic growth. Firms should proactively employ green policy funding to foster green technology innovation, mitigate environmental pollution, and enhance energy and production efficiency. These actions not only enhance the long-term competitiveness of firms but also contribute to green development.

(3) Investors can use the findings to make well-informed decisions, giving priority to investments in green projects and technologies that are in line with green economic objectives. This study broadens the scope of investment possibilities in green initiatives that possess strong sustainability and receive significant financial and legislative support from the government. Investors can enhance the performance of their portfolios and attain sustainable investment returns by prioritising green projects. These projects provide both environmental sustainability and reliable financial returns, thanks to government support.

To summarise, this study presents a thorough analysis that not only enhances theoretical comprehension but also provides practical recommendations for attaining green economic growth. Policymakers, businesses, and investors could utilise these findings to formulate efficacious policies and render well-informed choices that bolster green economic growth.

1.6 Definition of Terms

This section provides the definitions of several terms used in the study. However, a more detailed explanation is discussed in Chapter 2.

Green Economic Growth

Green economic growth is based on the principle of sustainable development with the goal of coordinating economic, social, and environmental development with the realisation of ecological, low-carbon, and circular economic development as the main content (Zvarych et al., 2023).

Green Finance

Green finance refers to the provision of funds for environmentally friendly initiatives that aim to develop a circular economy, including boosting clean energy, lowering greenhouse gas emissions, and supporting other environmental issues (Banga, 2019).

Industrial Structure Upgrading

Industrial structure upgrading is the process of changing a whole industry from a low-level structure to a high-level structure (Song et al., 2021).

Green Technology Innovation

Green technology innovation, also called clean technology innovation, encompasses using green energy, equipment upgrades, and process enhancements to conserve energy, mitigate pollution, and optimise production efficiency (Barbieri et al., 2020; Xie & Teo, 2022).

Social Progress

Social progress refers to a society's capacity to provide fundamental needs, create opportunities for individuals and groups to enhance and maintain their current standard of living, and establish the conditions required for each person to achieve their maximum potential (Boulton, 2022).

1.7 Organization of the Chapters

The study is structured into five chapters. Chapter 1 introduces the research background, followed by the problem statement, the objectives and questions, the significance of the study, and the definition of terms. Chapter 2 offers a comprehensive review of the relevant literature and identifies existing gaps, followed by an introduction to the related theories, including Green Finance Theory, Industrial Diffusion Theory, and Porter Hypothesis Theory. The chapter then explains the formulation of the hypotheses and presents the research framework. Subsequently, chapter 3 outlines the methodologies used in the research process to ensure the efficient progression of the subsequent empirical analysis. This chapter comprehensively describes the study sample, data source, data analysis methodologies utilised, and the research models employed for panel regression. The final section involves the selection and measurement of all variables.

Chapter 4 conducts the empirical tests and analyses the findings of this study. This chapter performed a descriptive statistical analysis, correlation analysis, multicollinearity test, unit root test, and cointegration test. This chapter employs various econometric models to examine Hypothesis 1. The stepwise regression approach is used to evaluate Hypotheses 2 and 3, while the modified Sobel test is employed to conduct the robust test. Chapter 5 summarises this study's main findings and offers suggestions based on those findings. This chapter also discusses the theoretical and practical contributions of the study after addressing the conclusion. Lastly, the study addressed its shortcomings and potential areas for future research.

CHAPTER 2

LITERATURE REVIEW AND RESEARCH FRAMEWORK

2.1 Introduction

This chapter starts off by introducing the notion of green economic growth, followed by an examination of its indicators. Next, the notion of green finance and the corresponding studies are examined, followed by a discourse on the upgrading of industrial structure and green technology innovation. Section 2.6 focuses on the relationship between green finance and green economic growth. In Sections 2.7 and 2.8, the paper discusses the role of industrial structure upgrading and green technology innovation in mediating the relationship between green finance and green economic growth. Gaps in the literature are put forward in Section 2.9.

Section 2.10 introduces three key theories relevant to the study: the Green Finance Theory, Industrial Diffusion Theory, and Porter Hypothesis Theory. The practical applications of these theories in supporting green economic growth are analysed, establishing a strong theoretical basis for this study. After presenting the theoretical concepts, Section 2.11 outlines the study's hypotheses. This section presents a structured overview of the assumptions regarding the beneficial effects of green finance on green economic growth, as well as the mediating roles played by industrial structure upgrading and green technology innovation. The study tries to elucidate the complex interplay between these variables and their combined impact on green economic growth by formulating these hypotheses.

In Section 2.12, the conceptual framework of this study is presented, integrating the abovementioned theories and hypotheses into a unified model. This framework acts as a guide for the subsequent analytical and empirical analyses, guaranteeing a methodical approach to studying the relationship between green finance, industrial structure upgrading, and green technology innovation in promoting green economic growth. Finally, Section 2.13 offers a concise summary of the chapter, highlighting the main issues and preparing for the in-depth empirical study that comes in the following chapters. This chapter not only establishes the foundation for the study but also situates it within the broader discourse on green economic growth, highlighting the crucial importance of green finance, industrial structure upgradation, and green technology innovation in attaining green economic growth.

2.2 Green Economic Growth

The emergence of a green economy or green economic growth has a well-documented practical background. In 1989, British environmentalist Pierce first introduced the concept of a "green economy" in his seminal work "Blueprint for the Green Economy" (Giordano, 2014). Pierce believes that the green economy aims to create a new economic model to satisfy the needs of both the natural environment and human beings for sustainable development, considering the prevailing ecological conditions. The green economy is characterised by efforts to enhance human well-being, reduce inequalities, and protect future generations' ecological scarcity and associated environmental risks (Lorek & Spangenberg, 2014).

The notion of green economic growth was subsequently established in 2005 to tackle the sustainable development challenges encountered by the swiftly advancing countries of Asia (Jänicke, 2012). The OECD conducted a study in 2009 that provides a more detailed explanation of this concept. They define it as an economic model that is both environmentally sustainable and utilises natural resources efficiently. The OECD highlights that green growth fosters economic progress while safeguarding vital resources and the environment (Fernandes et al., 2021). Green economic growth is based on the principle of sustainable development with the goal of coordinating economic, social, and environmental development with the realisation of ecological, low-carbon, and circular economic development as the main content (Zvarych et al., 2023).

Furthermore, green economic growth is a distinct approach that focuses on achieving a sustainable balance between environmental risks and economic growth over the long term. Green economic growth has generated global attention and is seen as a viable strategy for reducing environmental degradation, preserving resources, and fostering economic growth (Musango et al., 2014). Also, green economic growth enhances resilience and ensures optimal and effective exploitation of resources without impeding development. Although there may be differences in its definitions, there is a strong consensus that it involves achieving both ecological sustainability and economic expansion. Hence, this study uses the definition provided by Zvarych et al. (2023).

2.2.1 The Indicators of Green Economic Growth

The indicators of green economic growth are essential for monitoring and evaluating its progress and performance. Due to the complex nature of green economic growth, researchers employ multiple techniques to develop the indicators. Some studies utilise green GDP as an indicator of the green economy due to its incorporation of environmental costs into traditional GDP, thereby capturing the balance between ecosystems and economic systems (F. Ahmed et al., 2022; Sohag et al., 2019). For instance, F. Ahmed et al. (2022) compute the green GDP by adding the GDP and educational expenditures while subtracting resource consumption and pollution expenses. Furthermore, certain studies examine green economic growth via the lens of production efficiency, positing that the green economy aims to achieve a higher level of desirable output and a lower level of undesirable output using less input (Houssini & Geng, 2022; Streimikis & Saraji, 2022; X. Zhao et al., 2022). In this respect, X. Zhao et al. (2022) selected five input indices: the desirable output (GDP) and undesirable outputs (industrial wastewater discharge, industrial sulphur dioxide emissions, and industrial smoke emissions). However, the majority of related literature only focused on measuring a single indicator or production efficiency method, which limited its ability to provide a comprehensive evaluation of green economic growth.

To address this problem, different organisations and countries have put forward extensive measures for assessing green economic growth. However, a globally united index system has not been established yet. Particularly, indicator selection involves choosing a framework to direct the assessment of green economic growth and then ensuring that the selected indicators encompass all components of this framework. Thus, the OECD has delineated a framework comprising three distinct categories: production, consumption, and environment. The OECD strategy includes five interconnected measurement categories, as outlined by the OECD (OECD, 2017): (i) indicators measuring the environmental efficiency of production and changes in production patterns; (ii) indicators measuring the environmental efficiency of consumption and changes in consumption patterns; (iii) indicators measuring the stocks of natural capital and environmental quality; (iv) indicators measuring the objective and subjective environmental quality of life; and (v) indicators measuring the responses of economic actors as shown in Figure 2.1.

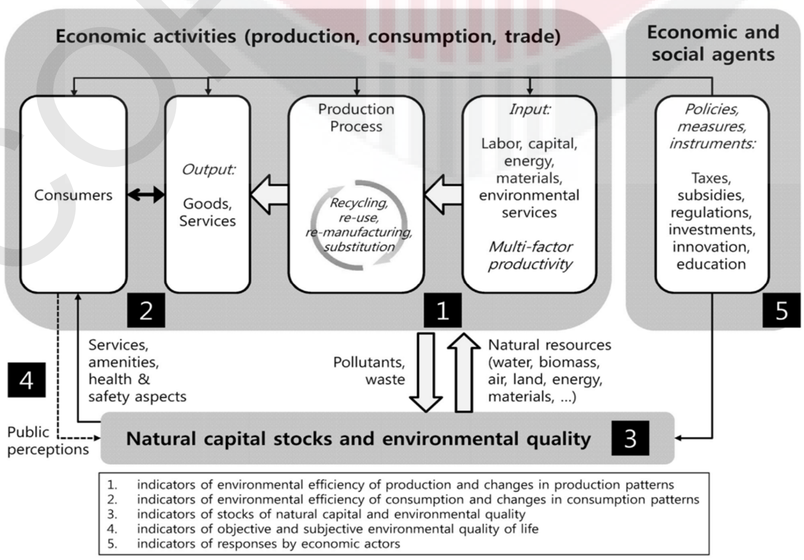

Figure 2.1: The OECD framework comprising five measurement categories for selecting green growth indicators

The OECD framework is based on the concept of a "network," highlighting the interconnectedness between indicators. The framework allows for the inclusion of sub-national indicators of development; however, its main focus is on indicators that are relevant to national, international, and global decision-making. In 2017, the OECD published the Green Growth Indicators Report, which includes 156 segmentation indicators (OECD, 2017). These reports have continually refined and expanded the framework for green growth, providing greater clarity and robustness. Also, the list of indicators in these reports is designed to be adaptable, allowing countries to customise it according to their specific circumstances. Despite this, a significant limitation of the OECD measures is the restricted availability and dependability of data (Engelmann et al., 2019). The World Bank's indicator system, introduced in 2013, comprises three primary indicators: environmental, economic, and social benefits, as well as six secondary indicators (Rastogi et al., 2023). Similarly, the Green Growth Knowledge Platform (GGKP) indicator system comprises three categories: national status, social development, and resource and environmental sustainability (Platform, 2013).

Nevertheless, due to the lack of widespread recognition of these indices, some scholars endeavour to create their own green growth index. Basically, the concept of green economic growth aligns with the three pillars of sustainable development, highlighting the interdependence of economic, social, and environmental development (Nielsen et al., 2014). For instance, J. Zhao et al. (2022) assess the green growth index using three dimensions: economic growth, people's welfare and livelihood, and resource and environment. They employ a total of 24 indicators. In order to conduct a more in-depth examination of green growth, the entropy weighting approach is utilised to assess 45 Asian countries by partitioning the Green Growth Index into two primary dimensions: economic-social and resource-environmental (Shao et al., 2022). This analysis employs 10 specific indicators. The summary of sustainable economic growth indicators is shown in Table 2.1.

Table 2.1: Summary of green economic growth indicators

Methods of index construction	Author	Indicators
The single indicator	Ahmed et al., 2022	Green GDP= GDP + education expenditure - the cost of resource and pollution
Production efficiency (More desirable output and less undesirable output with less input)	X.Zhao et al.,2022	(1) The desirable output (GDP). (2) The undesirable output (3) Five inputs (Capital, labour, land, energy, water).
Comprehensive index	OECD, 2017	(1) Environmental efficiency of production and changes in production patterns (2) Environmental efficiency of consumption and changes in consumption patterns (3) Stocks of natural capital and environmental quality (4) Environmental quality of life (5) Economic actors' responses
	World Bank, 2013	(1) Environmental benefits (2) Economic benefits (3) Social benefits
	Green Growth Knowledge Platform, 2013	(1) National status (2) Social development (3) Environmental sustainability
	Nielsen et al., 2014	(1) Economy (2) Society (3) Environment
	J. Zhao et al.,2022	(1) Economic growth (2) People's welfare and livelihood (3) Resource and environment

In summary, accurately assessing the overall state of green economic growth is essential for any country or region; however, existing research in this area remains insufficient. First, both the single indicator and the production efficiency method have their design and application limitations, making them unable to provide a comprehensive evaluation of green economic growth. Second, there is currently no unified, comprehensive index of green economic growth globally. Previous indicators predominantly focus on economic and environmental benefits, neglecting social or resource consumption. Consequently, this study will attempt to create a new comprehensive index that accurately reflects the status of the environment, economy, society, and resource conservation. This effort seeks to address the existing gap in a globally recognised index.

2.2.2 Relevant Studies of Green Economic Growth

Since green economic growth represents the overarching goal and outcome of various initiatives within a country or region, previous studies have concentrated on its driving forces. These driving forces primarily include financial, industrial, technological, political, openness, and energy consumption factors.

Regarding the financial factor of economic growth, current studies mostly concentrate on financial development, financial agglomeration, and green finance. Since financial development increases the ability and inclination of people and businesses to borrow funds, it can potentially boost consumer demand for high-energy products. Therefore, the expansion of financial institutions may unintentionally impede the progress of environmentally sustainable growth by amplifying resource utilisation and releasing pollutants (Cai et al., 2019). Nevertheless, an enhanced financial system enables governments to reallocate funds towards ecologically advantageous initiatives (Ayayi & Wijesiri, 2022). Financial agglomeration promotes urban green economic growth in China through both direct effects and spatial spillover effects (Tian et al., 2021). Furthermore, green finance promotes investments that prioritise energy conservation and pollution reduction, enabling a shift from environmentally polluting projects to more sustainable alternatives (D'Orazio & Popoyan, 2019). Green finance strengthens green economic growth in Belt and Road Initiative member countries as well as in G20 economies (Ma et al., 2023; Zhang et al., 2021). However, there is a conflicting finding that green finance deteriorates carbon emission intensity in Chinese provinces through structural transformation (Gan & Voda, 2023), which is detrimental to green economic growth.

When it comes to the industrial factor, it is essential to consider important aspects such as upgrading and transformation of the industrial structure. Industrial structure upgrading could guide the flow of production elements to more productive sectors, essentially achieving a balance between factor productivity in each sector and the development of economic growth (Peneder, 2003). Furthermore, the transformation of the industrial structure contributes to the conservation of energy and the reduction of emissions, promoting sustainable economic growth (Shimada et al., 2007). Studies suggest that improvements in the industrial framework, linked to enhanced productivity and efficient utilisation of resources, decrease CO_2 emissions in the Beijing-Tianjin-Hebei region of China (Chen et al., 2019).

In terms of the technological innovation factor, innovation in technology and its subsequent consequences offer substantial prospects for economic growth in developing nations (Ilkay et al., 2021; Seck, 2012; Tientao et al., 2016). Technological innovation has improved the variety of elements used in production, which has led to the development of a green economy (Koren & Tenreyro, 2013). As studies on sustainable growth increase, researchers are placing more emphasis on the essential role of green technology innovation. It reduces pollution and environmental harm in BRICS nations by improving technology innovation and materials for environmental protection (Sharma et al., 2021). Green technology innovation in developed countries has been shown to enhance sustainability by lowering carbon emissions (Sharif et al., 2022).

Regarding the political factor, environmental regulation is the main focus in most of the literature. It is a common feature of Chinese government behaviour that influences local green performance through mechanisms such as the Porter effect and the pollution shelter effect (Peng, 2020). Empirical studies have demonstrated how environmental regulation affects pollution in China, revealing that it triggers pollution transfer by virtue of a spatial self-lag model (Xu et al., 2023). Nevertheless, regional green economic growth is adversely affected by environmental restrictions. For instance, stricter environmental regulations negatively impact economic growth in the UK due to higher environmental costs for businesses during manufacturing (Demirel & Kesidou, 2011).

Concerning the factor of openness, foreign investment directly contributes to reducing carbon emissions and promoting green energy generation in Singapore and China, specifically in relation to openness as a factor of green economic growth (Mohsin et al., 2021). Foreign direct investment (FDI) contributes to green economic growth by promoting the spatial agglomeration effect (D. Yu et al., 2021). Nevertheless, the positive effects of FDI may decline as the market system develops (Chai et al., 2021). Trade openness has been shown to significantly enhance green productivity, as it facilitates the exchange of information, technology, and financial resources among countries (Chai et al., 2021).

In relation to the energy consumption factor, the consumption of renewable energy has the potential to completely replace fossil fuels, thereby promoting economic growth as well as a green society in the Mercosur countries (Koengkan & Fuinhas, 2020). The relationship between the change in energy consumption and green total factor production exhibits an inverted "N" shape, suggesting that positive effects can only be achieved within a specific range of energy consumption transitions (Xie et al., 2021).

Table 2.2: Summary of relevant studies on green economic growth

Authors	Influencing Variables		Findings
Cai et al. (2019), Ayayi & Wijesiri (2022).	Financial factor	Financial development	The rise of financial institutions may impede green growth.
Tian et al., (2021).		Financial agglomeration	It benefits urban green economic growth in China.
Ma et al. (2023), Zhang et al. (2021).		Green finance	It promotes green economic growth in Belt and Road Initiative member countries as well as in G20 economies.
Gan & Voda (2023).			It promotes carbon emission intensity through structural transformation in Chinese provinces.
Peneder (2003), Jing et al. (2021).	Industrial factor	Industrial structure upgrading	It has been found to promote economic growth.
Chen et al. (2019).		Industrial structure transformation	It promotes emission reduction in China.
Ilkay et al. (2021).	Technological factor	Technological innovation	It facilitates economic growth in developing countries.
Sharif et al. (2022).		Green technology innovation	It benefits environmental quality in developed countries.
Demirel & Kesidou (2011).	Political factor	Environmental regulation	It adversely affects economic growth in the UK due to the increased cost of pollution-reduction efforts.
Y. Xu et al. (2023)			Environmental regulation improves local green performance in China.
Mohsin et al. (2021).	Openness factor	Foreign investment	It is beneficial to carbon emissions reduction in Singapore and China.
Koengkan & Fuinhas (2020).	Energy factor	Energy consumption structure	It promotes green economic growth in the Mercosur countries.

As presented in Table 2.2, these results show that attaining green economic growth depends critically on different factors. For the financial factors, this study finds that green finance provides financial support to eco-friendly activities and restricts pollution projects in Belt and Road Initiative member countries as well as in G20 economies based on green policies. In contrast to traditional finance, green finance focuses more on environmental than merely financial gains. Therefore, green finance can accomplish a change towards green development more effectively than traditional finance. However, scholars also have a different opinion that green finance has an enhancing effect on carbon emission intensity in China through structural transformation (Gan & Voda, 2023), which is detrimental to green economic growth. Therefore, research on the relationship between the impacts of green finance and green economic growth needs to be further explored.

For the industrial factors, industrial structure transformation basically transfers low productivity sectors to high productivity sectors (F. Li et al., 2022). Additionally, industrial structure upgrading refers to a changing process in whole industries from low-low to high-leave, representing the increase of tertiary industry and the decrease of primary and secondary industries (Song et al., 2021). It involves the improvement of production value and the reduction of environmental pollution, which can obtain environmental benefit as well as economic benefit. This is because the tertiary industry has the highest added value and lowest pollution, as it mostly consists of service sectors, software, and information technology. The primary and secondary sectors exhibit significant levels of consumption, pollution, and reliance on resources, with the secondary industry being more prominent in these aspects. Therefore, the upgrading of industrial structures would make a great contribution to the shift toward green economic growth.

For the technological factors, in contrast to the factor of traditional technology that primarily focuses on economic development, green technology innovation prioritises the integration of economic benefits and environmental preservation by connecting technology and the environment (Braun & Wield, 1994). Green technology innovation encompasses using green energy, equipment upgrades, and process enhancements to improve productivity and clean energy usage (Barbieri et al., 2020). As a result, it could have a greater enhancement of green economic growth than traditional technology through increased productivity and reduced pollution.

In general, this research further finds that green finance, industrial structure upgrading, and green technology innovation all have a crucial impact on green economic growth through improved environmental and economic benefits. As a result, an in-depth analysis of these influencing factors and their relationships is discussed in the subsequent sections. This thorough review seeks to clarify their combined influence on realising a green economy.

2.3 Green Finance

Green finance offers financial assistance or initiatives focused on establishing a circular economy, such as developing clean energy to decrease greenhouse gas emissions and conducting financial activities to achieve other environmental goals (Banga, 2019). The financial strategy known as "green finance" has gained significant global acceptance and is crucial for ensuring green development, which is considered the key driver of sustainable growth. Green finance gained visibility in 1992 when guiding papers like "Agenda 21" were released and put into practice (Risheng, 2012). Subsequently, Salazar, in 1998, emphasised the distinction between conventional finance and green finance, contending that the latter prioritises both ecological conservation and economic advancement (Bakry et al., 2023). He defined it as a collection of inventive financial activities that are in line with economic policies and environmental protection systems.

In October 2016, the G20 summit further emphasised the concept of green finance, which aims to promote sustainable development through financial practices. In addition, green finance refers to the provision of funds for projects that aim to develop a circular economy, promote clean energy, reduce greenhouse gas emissions, and support other environmental goals (Banga, 2019). Hence, green finance prioritises environmental considerations more than traditional finance, with resource efficiency and environmental protection being important measures of success (Zhou et al., 2020).

In this respect, policymakers and researchers have paid close attention to it as a long-term financial instrument for green economies. As a result, various studies have studied variables impacting the growth of green finance, with a primary focus on government policy, the financial system, and fintech.

In terms of the government policy factor, green finance serves as a financial tool designed to encourage the growth of a circular economy, and its development is inextricably dependent on the government's support and guidance. Since the United Nations launched the Environmental Protection Agency Banking Plan in 1992, the standards for green finance have been continually improved. To increase the amount of green investment from businesses, governments in European regions employ various management strategies, including direct environmental regulation, the sale of pollutant discharge rights, the collection of pollution discharge fees, and subsidies (Leiter et al., 2011). For instance, environmental policies have been shown to significantly facilitate green finance in China (Peng & Zheng, 2021).

Furthermore, achieving comprehensive green economic growth necessitates the greening of the financial system as a foundational step. The G20 Summit in 2016 launched a worldwide plan to green the financial system (Gilchrist et al., 2021). This plan emphasised the financial system's ability to support green financial models and guarantee that financial institutions accurately price environmental and carbon risks (Tienhaara, 2016). The process of greening the financial sector can be greatly hastened by government fiscal and monetary policies (Batrancea et al., 2020).

Regarding the fintech factor, which pertains to the implementation of technology in financial services such as mobile payments and asset management (Yang et al., 2021). Fintech, utilising big data analytics and artificial intelligence, takes a prominent position in offering green finance and promoting a shift towards sustainability for consumers and small and medium enterprises (H. Xu et al., 2020). Furthermore, Fintech has been credited with facilitating the extensive adoption of environmentally friendly agricultural practices in China by ensuring the availability of financial resources, bridging information gaps, and enhancing trust and belief among farming communities (L. Yu et al., 2020).

In this context, numerous studies have primarily concentrated on the impacts of green finance, emphasising its function in offering financial backing for green initiatives and its subsequent influence on both economic and environmental development. The primary focus of these studies is on those major areas: industrial structure upgrading, energy conservation and emission reduction, green economic growth, and the behaviour of firms and banks.

In terms of the effect on industrial structure upgrading. Green finance has been found to promote the upgrading of industrial structures through restricting pollution activity in China (Wang & Li, 2022). Similarly, as highlighted by Lv et al. (2021), the primary goals of green finance encompass the conscientious management and conservation of the environment. Their findings emphasise the efficacy of green financing in redirecting cash from polluting industries to ecologically friendly industries.

Regarding the impact on economic growth, green finance has been demonstrated to promote sustainable development by channelling capital into eco-friendly initiatives and technology, hence fostering economic growth (Van

Niekerk, 2024). In comparison to traditional finance, green finance prioritises resource efficiency, which is a critical factor in determining the effectiveness of its initiatives (Wang & Zhi, 2016).

Moreover, green finance is crucial for encouraging investments in renewable energy and energy-efficient technology, which are essential for conserving energy and reducing emissions. It promotes the shift towards a green economy by funding projects that prioritise lower energy consumption. It has also been demonstrated to enhance resource utilisation, decrease pollutant emissions, and impact energy savings and emission reduction. Studies have examined the influence of green finance on CO_2 emissions in countries with significant levels of green finance. Carbon reduction is adversely affected by green funding in both BRICS countries (X. Wang et al., 2021) and OECD nations (T. Wang et al., 2023).

In terms of the impact on green economic growth. As the international community and government attach importance to green economic growth, a growing number of scholars study the role of green finance in promoting green economic growth. For instance, green finance enhances green development by supporting green projects in both wealthy and poor nations (Afzal et al., 2022; Zhang et al., 2021). However, there is a conflicting finding that green finance has an enhancing effect on carbon emission intensity in Chinese provinces through structural transformation (Gan & Voda, 2023), which is detrimental to green economic growth.

Furthermore, regarding the impact on firms' behaviour, enterprises are motivated to embrace sustainable practices and allocate resources towards green technologies in order to obtain funding. Traditional financial operations prioritise profit as the sole factor in choosing investment projects, neglecting considerations of the environment. This approach hinders the promotion of investments in green businesses (Tamazian & Bhaskara Rao, 2010). Extensive studies have examined the correlation between green financial policies and the investment behaviour of polluting businesses. For instance, Lee (2020) discovered that adopting green finance could limit the investment activities of companies with high pollution levels in China. He et al. (2019) emphasised that it also inhibited the finance and investment capacities of Chinese polluting firms while only exerting a weak positive influence on their economic performance. By reducing financing and compressing loan stocks for energy-intensive and high-pollution businesses, green finance prevents innovation in those sectors (Chang et al., 2019).

Additionally, the progress of green innovation can be impeded when businesses encounter increased financial constraints, with privately owned enterprises being more susceptible than state-owned ones. In this respect, Madaleno et al. (2022) examined the role of green finance in providing financial assistance for green technology in a global outlook, which in turn helps achieve energy transition.

Regarding the influence on the behaviour of financial suppliers, including banks. Particularly, studies have concentrated on factors like risk, competitiveness, and financial performance. X. Zhou et al. (2022) discovered that the implementation of green credit plan resulted in an escalation of credit risk for urban and regional commercial banks while simultaneously reducing it for state-controlled banks in China. Moreover, Luo et al. (2021) found that green credit affected the overall competency of banks, particularly urban and rural commercial banks. Nevertheless, the impact of this effect has diminished in the years subsequent to the announcement of the program. Furthermore, Yin et al. (2021) found that the implementation of green credit policies enhanced the profitability and risk reduction of non-state-owned banks. However, state-owned banks may face a decrease in earnings because of these policies.

Table 2.3: Summary of relevant studies in the field of green finance

Authors	Independent Variables	Dependent Variables	Findings
Leiter et al. (2011)	Government policy	Green finance	Its development depends on local government's assistance in European regions.
Berensmann & Lindenberg (2019)	Financial system	Green finance	The financial system forces green financial institutions to price environmental and carbon risks appropriately.
L. Yu et al. (2020)	Fintech	Green finance	Fintech benefits the provision of green finance and encouraging a green transition among consumers and SMEs.
Wang & Li (2022)	Green finance	Industrial structure upgrading	It promotes the upgrading of industrial structures in China.
Salazar (1998)	Green finance	Energy conservation and emission reduction	It reduces carbon dioxide and other harmful gas emissions in BRICS countries and OECD nations.
Afzal et al. (2022), Zhang et al. (2021)	Green finance	Green economic growth	It effectively improves green growth in both wealthy and poor nations.
Gan & Voda (2023)			It increases carbon emission intensity in Chinese provinces through structural transformation, which is detrimental to green economic growth.
Lee (2020)	Green finance	Enterprises' investment	Polluting businesses investment is severely restricted by green finance in China.
He et al (2019)	Green finance	Enterprises' financing	It has obvious financing penalty effects on Chinese polluting enterprises.
Madaleno et al. (2022)	Green finance	Enterprises' green technology innovation	Green credit provides enterprises with green innovation funds in a global outlook.
X. Y. Zhou et al. (2022)	Green finance	Bank's risk	China's green credit resulted in credit risk for urban and regional commercial banks.
Luo et al. (2021)	Green finance	Bank's competitiveness	It improves the competitiveness of banks in China.
Yin et al. (2021)	Green finance	Bank's financial performance	Green credit improves the profitability of non-state-owned bank.

Table 2.3 presents the summary of relevant studies in the area of green finance. These studies emphasise the significance of green finance in advancing both energy conservation and its contribution to the environment **in** BRICS and OECD nations. It also has a beneficial effect on green economic growth in developed and developing nations. Different from traditional finance, green finance distinguishes between environmental protection and pollution projects and then provides financing support for green projects. This gives it additional environmental protection functions, thus upgrading green development. However, there is a conflicting finding that green finance improves carbon emission intensity in Chinese provinces through structural transformation, which is detrimental to green economic growth. Besides, the upgrading of industrial structures in China has also been promoted by green finance due to the provision to the green industry.

In addition, from a micro perspective, green finance brings diverse effects on businesses. For instance, green finance has a crucial effect on enterprises' investment and financing in China because of its financial supply attribute. Besides, it also stimulates green innovation activities of enterprises in a global outlook. By alleviating financing constraints, green finance encourages enterprises to pursue green innovations. It can also guide the green behaviour of enterprises through green finance policies. Therefore, green technology innovation could be stimulated by green finance through green financial policy.

In general, previous studies in the literature have discovered that green finance has an enhancing effect on the green technology innovation of enterprises. It also facilitates the upgrading of industrial structures as well as green economic growth. As a result, green finance has a close link with green technology innovation, the upgrading of industrial structures, and green economic growth. Therefore, the above relationships will be further discussed in the following sectors.

2.4 Industrial Structure Upgrading

Industrial structure upgrading is the process of changing and improving the composition and efficiency of a country's or region's industrial sectors. This notion entails redirecting resources from less productive and frequently polluting industries to more productive and sustainable ones. As discussed earlier, industrial structure upgrading is also an essential contributor to green economic growth. Within the realm of economic development, there is variation in the extent of resource consumption across different industries. The secondary industry, in particular, exhibits the highest level of resource consumption and inflicts the most significant harm upon the ecological environment. Conversely, the tertiary industry boasts the highest added value and generates the least pollution (Jing et al., 2021).

The notion of industrial structure emerged in the seventeenth century. According to the economist W. Petty, disparities in national income levels and economic growth among countries are mostly caused by variations in their industrial systems (Houghton, 1941). In his influential treatise "Political Arithmetic," which was published in 1672, Petty deduced from his research that industry produces a greater income than agriculture, and commerce provides a higher income than industry. This indicates that the industry sector has a greater level of value contributed compared to agriculture but a lesser level compared to commerce. Industrial structure pertains to the makeup and relative distribution of various industries in an economy, along with the interconnectedness between these industries (Shen, 2018).

The proportional composition of each industrial sector varies, resulting in differing levels of contribution to economic growth. This involves the allocation of resources, labour, and capital among several sectors, including primary (agricultural, mining), secondary (manufacturing), and tertiary (services) industries. The basic industry, which mostly includes agriculture, involves the extraction of resources straight from nature without further processing. The secondary industry is concerned with the processing of natural resources and the transformation of raw materials, which generally includes manufacturing and construction. The tertiary industry provides consumer services and preferences, encompassing finance and other service areas (Jing et al., 2021). In economic development, the degree of resource consumption varies between different industries; the secondary industry consumes resources the most and causes the greatest harm to the natural environment, while the tertiary industry consumes the least (Jing et al., 2021).

Industrial structure upgrading refers to the transformation of an entire industry from a lower-level structure to a higher-level structure (Song et al., 2021). From a national or regional perspective, it is apparent in the shifting trend of the share of various industrial sectors. In particular, the third industry's size continues to grow as the first and second sectors decrease. From the internal structure of the industrial sectors, it can be seen in the shift from low-value, labour-intensive industrial chains to high-value, technologically intensive industrial chains, as well as the ongoing increase in production efficiency. This process leads to the redistribution of resources from inefficient industries to efficient industries, thereby improving total productivity and promoting economic growth (Gong, 2018). This study adopts the definition of industrial structure upgrading as proposed by Song et al. (2021).

There are many driving forces influencing industrial structure upgradation, such as supply structure (resources, labour, technology, and finance), international investment and trade, and government policy.

Regarding the factor of supply structure, which mainly includes resources, labour, technology, and finance. For example, Liao et al. (2023) indicate that China's natural resources have a significant role in improving its industrial structure, resulting in a short-term benefit known as the industrial structure dividend effect. Navaneetham (2002) finds that demographic shifts in population age structure in South and Southeast Asia have a favourable effect on industrial structure by increasing employment rates and promoting more capital accumulation. The increasing number of ageing people substantially impacts the transition towards a service-based tertiary industry. This transition is closely related to upgrading the industrial structure (Shen et al., 2022). Moreover, technical progress in the Netherlands is crucial in reshaping industrial frameworks by improving efficiency and facilitating the shift from industries reliant on manual labour to those reliant on advanced technology (Marsili & Verspagen, 2002).

In terms of the factor of finance, the strong expansion of the financial sector has allowed enterprises to obtain capital from many sources, resulting in a dynamic and changing corporate environment that enhances the efficiency of the industrial structure (Cetorelli & Gambera, 2001). The influence of financial development on upgrading industrial structures is significant. However, it is influenced by a triple-threshold effect related to environmental regulation (Xu & Tan, 2020). Furthermore, green finance in China has the specific objective of safeguarding and overseeing the environment by redirecting resources from industries that cause pollution to sectors that are environmentally friendly. This, in turn, promotes sustainable industrial transformation (Lv et al., 2021).

Concerning the factor of international investment and trade, China has taken advantage of industrial upgrading prospects by investing in emerging and Belt and Road countries (Chen et al., 2020). Foreign direct investment (FDI) and international commerce play critical roles in improving industrial structures by introducing cutting-edge technology, managerial methods, and environmental protection principles. Imports and exports not only help to upgrade local industries, but they also catalyse similar improvements in other locations, resulting in a ripple impact on global industrial progress (Wang et al., 2020). This continually changing interplay between foreign investment and trade emphasises their importance in driving industrial innovation and promoting economic growth. By capitalising on global markets and investment opportunities, economies can speed industrial upgrading, improve competitiveness, and promote long-term growth on both domestic and international scales.

In relation to the factor of government policy, including tax policies and environmental restrictions. Energy taxes, for instance, not only enhance energy efficiency but also drive industrial structure optimisation in Bangladesh (Uddin et al., 2023). Environmental regulations provide financial and other benefits to enterprises that invest in technical innovation and help shift towards more sustainable industrial structures (Chen & Qian, 2020). By implementing stringent environmental regulations, nations can reduce their dependence on natural resources, promote economic diversification, and address challenges such as the Dutch disease (Shehabi, 2020).

At the same time, the process of improving industrial structures unavoidably influences both the economy and society. As a result, studies have carried out thorough investigations on these impacts, such as economic expansion, resources, and green economic growth.

In terms of the impact on economic growth, industrial structure has been found to enhance economic growth through the income elasticity of demand and the structural bonus in 28 OECD nations (Peneder, 2003). In addition, the cyclic nature of the industrial structure has an impact on economic fluctuations and promotes overall economic growth (Dong et al., 2011). In light of the emergence of the green economy, researchers have shifted their attention towards comprehending the influence of industrial structure on environmental sustainability. The secondary sector, which is primarily responsible for energy consumption and carbon emissions, highlights the possibility of making adjustments to the industrial structure in order to successfully decrease carbon emissions (Ma et al., 2019). For instance, the upgrade of China's industrial structure has significantly helped to decrease carbon emissions and progress its high-quality growth trajectory (Hu et al., 2021).

Moreover, changes in industrial structure have a dramatic impact on the structure of energy consumption in Pakistan, which in turn affects the magnitude of energy use (Ahmed & Zeshan, 2015). Resource-rich regions often face challenges associated with the resource curse, particularly when their economies are heavily reliant on industries dependent on a single resource (Wu et al., 2018). Nevertheless, energy-rich regions can mitigate the negative impacts of resource availability on industrial development by improving their industrial structure and diversifying their economies (Wu et al., 2021).

Considering the impact on green economic growth, the main catalyst for decreasing carbon emissions is shifting from heavy industries to technology and services industries (Green & Stern, 2017). For instance, Pakistan's carbon intensity experienced a decline as its green industry underwent change from 1975 to 2020 (Mehmood et al., 2024). The transition from primary and secondary sectors to tertiary sectors enhances the efficiency of green growth (Zhu et al., 2019).

Table 2.4: Summary of relevant studies in the field of industrial structure upgrading

Authors	Independent Variables	Dependent Variables	Findings
Liao et al. (2023)	Resources	Industrial structure upgrading	Natural resources enhance industrial structure in China.
Navaneetham (2002)	Labour	Industrial structure upgrading	Changes in population age structure have an advantageous effect on the industrial structure in south and southeast Asia.
Marsili & Verspagen (2002)	Technology	Industrial structure upgrading	Technology improves the reshape of industrial structure in the Netherlands.
Lv et al. (2021)	Green finance	Industrial structure upgrading	It could divert funds from polluting sectors to green ones in China.
Wang et al. (2020)	FDI	Industrial structure upgrading	FDI is a significant force behind upgrading industrial structure by bringing advanced technology and management.
Uddin et al. (2023)	Government policy	Industrial structure upgrading	Energy taxes optimize industrial structure upgrading in Bangladesh.
Peneder (2003)	Industrial structure upgrading	Economic growth	It promotes economic growth through the income elasticity of demand and the structural bonus.
Ahmed & Zeshan (2015)	Industrial structure upgrading	Resource consumption	The structure of energy consumption will be impacted by the change in industrial structure in Pakistan.
Zhu et al. (2019)	Industrial structure upgrading	Green economic growth	It enhances the efficiency of green growth.

Table 2.4 displays a comprehensive overview of relevant studies on upgrading industrial structures. The upgrading of industrial structures in different regions could be driven by multiple factors, including natural resources, labour, technology, green finance, FDI, and government policy. Among them, green finance stands out as a unique driver, as it prioritises both environmental benefits and industrial progress, particularly in China. The tertiary industry, which mostly consists of software, information technology, and service sectors, generates the highest value-added output while maintaining the lowest levels of pollution. Therefore, the tertiary industry is mostly consistent with green financial policy due to its low pollution to the environment compared with the primary and secondary industries. As a result, green finance will contribute to the increase of the tertiary industry and the decrease of primary and secondary industries, resulting in the upgrading of industrial structures.

Furthermore, it has been found that the upgrading of industrial structures not only promotes economic progress but also contributes to the shift toward green economic growth. This is because industrial structure upgrading increases the added value of production and services, promoting economic growth. At the same time, it also reduces environmental pollution and resource consumption in Pakistan. These economic and environmental benefits ultimately facilitate the realisation of green development.

Therefore, industrial structure upgrading has close relationships with green finance as well as green economic growth. Those above relationships will be further discussed in the following sectors.

2.5 Green Technology Innovation

As earlier discussed, studies have demonstrated that green technology innovation reduces pollution and environmental harm by developing new technologies, processes, and materials for environmental protection (Sharma et al., 2021). Furthermore, it has the least negative impact on the environment (Liu et al., 2021). The concept of green technology innovation was initially developed by Braun and Wield. In 1994, they emphasised that green technology prioritises the integration of economic benefits and environmental preservation, in contrast to traditional technology that primarily focuses on economic development and overlooks environmental and resource protection (Braun & Wield, 1994). Businesses largely utilise green technology to adhere to increasingly demanding environmental laws and regulations. During this process, companies that possess cutting-edge environmentally friendly technology may engage in lobbying efforts to persuade the government to establish more rigorous requirements for environmental protection to uphold the competitive advantage of firms (Berry & Rondinelli, 1998).

Green technology innovation means that enterprises could save energy, decrease energy use, and boost efficiency in production through the adoption of green innovation (Barbieri et al., 2020; Xie & Teo, 2022). It is a process that involves applying new theories and technologies of environmental protection to production and operation, aiming to create environmental value and achieve economic benefits. Environmental conservation, technology, and economic development are the three main pillars of this innovation (Xiao & Xu, 2017).

The concept of green technology innovation encompasses two main aspects. Firstly, it involves incorporating resource conservation, ecological protection, and green development at every stage of technological innovation activity. Secondly, it aims to achieve harmonious coordination between economic, social, and environmental development (Zhuang et al., 2020).

This study considers green technology innovation as a form of ecological technology innovation aimed at achieving harmonious growth of the economy, society, and environmental development. Greening is the incorporation of environmentally friendly principles across the entire lifespan of a product. Hence, this study relies on the definition provided by Barbieri et al. (2020) and Xie and Teo (2022).

Green technology innovation, as a form of ecological technology, necessitates the assistance of both external and internal factors. External factors mostly encompass government regulation, green finance, and openness, whereas internal aspects primarily encompass R&D investment and corporate governance.

Regarding the factor of government regulation, including environmental control and government subsidies, it has received much attention in the literature. Porter and Linde proposed the "Porter Hypothesis," which states that strict environmental rules can motivate corporations to create environmentally friendly technologies, even though it may result in increased production expenses (Porter & Van der Linde, 1995). Nevertheless, Calel and

Dechezleprêtre (2016) discovered that an abundance of environmental regulations in European could discourage companies from implementing green technology because of the associated rise in expenses. This suggests that there is a need for regulatory instruments that are specifically designed to address this issue. Hence, government subsidies have been recognised as a driving force in motivating Chinese corporations to invest in green technology, especially during the early phases of enhancing environmental laws (P. Wang et al., 2021).

In relation to the factor of green finance, it primarily stimulates the innovation of green technology by restricting funding for energy-intensive and highly polluting businesses, therefore encouraging innovation in green industries (Chang et al., 2019). Notably, to facilitate an effective transition towards sustainable development goals, green finance globally serves as a pivotal funding mechanism supporting environmental innovations (Madaleno et al., 2022).

In terms of the openness factor, FDI has been a focal point. Studies hold different opinions on the effect of green innovation, with research findings varying from positive outcomes to negative outcomes (García et al., 2013). Significantly, studies have shown that research activities benefit outcomes of imports, which have an adverse effect on the advancement of environmentally friendly technology (Costantini & Mazzanti, 2012). Moreover, the act of engaging in the exchange of green technology has been recognised as providing novel advantages stemming from transparency and accessibility (Losacker et al., 2023).

In relation to the factor of R&D investment, green R&D improves the efficiency of green technology transformation for industrial enterprises (Du et al., 2019). Furthermore, the positive relationship between R&D and eco-friendly innovation in China is influenced by the performance of social and governance factors (J. Xu et al., 2020).

Concerning the factor of corporate governance, scholars have found that when the top management has a high commitment to the environment, its response to the environment is stronger. That is, the more senior executives pay attention to environmental protection, the more they will actively respond to government and market requirements for green environmental protection, proactively seeking green technology innovation (Colwell & Joshi, 2013). According to Asni and Agustia (2022), certain governance structures, like board size, independent commissioners, and ownership concentration, enhance green innovation initiatives in emerging nations. The studies emphasise the diverse impact of governance in facilitating green innovation and advancing the long-term viability of companies.

In the meantime, green technology innovation is dedicated to improving productivity and environmental performance through innovation. Its impact extends to both the economy and businesses, primarily emphasising corporate development (corporate reputation and competitiveness), economic growth, and green growth.

In terms of the impact on corporate reputation, companies prioritising green innovation tend to have a positive corporate reputation, leading to greater social acceptance and benefits such as higher product prices (Darnall et al., 2007). Green process innovation can greatly improve a company's sustainability in Turkey (Sezen & Çankaya, 2013). In addition, the creation of green technology can enhance the reputation of enterprises in developed and developing nations, spreading the advantages of green products throughout their entire brand portfolio (Miroshnychenko et al., 2017).

Regarding the impact on corporate competition, green technology innovation has been shown to improve performance and competitiveness among organisations in corporate competition. For instance, Miroshnychenko et al. (2017) argue that green innovation improves companies' performance and competitiveness using a panel of 58 countries over 13 years. The capacity of organisations to develop green technology enhances their competitiveness; however, the impact on competitiveness may vary depending on the specific components involved. More specifically, the relationship between a firm's ability to adopt green technology innovation and its competitiveness is influenced by product differentiation and positively influenced by company size (Li et al., 2019).

With reference to the impact on economic development and green growth, technological innovation and its spillover effects present excellent potential for economic progress in emerging economies (Ilkay et al., 2021; Seck, 2012; Tientao et al., 2016). With the increasing focus on green development, researchers have started to investigate the contributory role of green technology innovation. It reduces pollution and environmental damage by developing new technologies, processes, and materials that prioritise environmental protection (Sharma et al., 2021). Its primary goal is to minimise the negative impact on the environment (Liu et al., 2021). Green technology innovation plays a vital role in achieving sustainable development by effectively balancing economic growth and environmental conservation in developed and developing countries (Abbas et al., 2024; Ikram et al., 2021; Mahmood et al., 2022).

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Table 2.5: Summary of relevant studies in the field of green technology innovation

Authors	Independent Variables	Dependent Variables	Findings
Calel & Dechezleprêtre (2016)	Environmental regulation	Green technology innovation	Excessive environmental regulation in European would prevent businesses from using green technology.
P. Wang et al. (2021)	Government subsidies	Green technology innovation	Government subsidies encourages Chinese companies to develop green technologies.
Madaleno et al. (2022)	Green finance	Green technology innovation	Green finance enhances green technology initiatives by employing global data.
Losacker et al. (2023)	Openness	Green technology innovation	Trading in green technology innovative benefits from openness.
J. Xu et al. (2020)	R&D investment	Green technology innovation	R&D expenditure promotes green innovation in China.
Asni & Agustia（2022）	Corporate governance	Green technology innovation	Effective governance mechanisms could encourage green innovation in emerging nations.
Miroshnychenko et al. (2017)	Green technology innovation	Corporate reputation	It enhances businesses' reputations in developed and developing nations.
Miroshnychenko et al. (2017)	Green technology innovation	Corporate competition	It improves the competitiveness of the company in a global outlook.
Koren & Tenreyro (2013)	Green technology innovation	Economic develop	It increases the variety of manufacturing input parameters, fostering economic growth.
Ikram et al. (2021), Mahmood et al. (2022)	Green technology innovation	Green growth	Green innovation benefits green development in developed and developing countries.

Table 2.5 summarises relevant studies on the innovation of green technology. This study finds that both external green finance as well as internal investment in innovation can effectively motivate enterprises to engage in green innovation behaviours. In particular, when enterprises' green innovations are constrained by internal investment capital limitations, green finance is capable of providing green financing support in global countries, thus eliminating capital constraints. Therefore, the green innovation activity of enterprises could be stimulated by green finance through releasing financing constraints.

Furthermore, the enhancement of green innovation capacity not only improves enterprise competitiveness but also promotes green economic growth in developed and developing nations. The relevant findings show that improved green innovation strengthens productivity, increases clean energy usage, and reduces environmental pollution in wealthy and poor nations. As an effective combination of technology and the environment, green technology innovation can additionally play an ecological protection role.

Therefore, this paper discovers that green technology innovation is closely related to green finance and green economic growth through summarising and discussing the related literature. Those above relationships will also be further discussed in the following sectors.

2.6 Green Finance and Green Economic Growth

Past studies have focused on green finance as a driver for environmental protection and carbon reduction. Compared to traditional finance, green finance prioritises environmental consideration to a greater extent (Zhou et al., 2020). For instance, green investments in India prioritise environmental preservation, mitigate environmental risks, and enhance ecological integrity (Soundarrajan & Vivek, 2016). Green finance promotes the transition from investments that consume a lot of energy and cause pollution to investments that safeguard the environment and promote energy conservation (D'Orazio & Popoyan, 2019). Environmental finance provides financial assistance for initiatives that protect the environment, mitigate pollution, save resources, and undertake other eco-friendly measures (Latif et al., 2022).

In this regard, the findings of Zahan and Chuanmin (2021) indicate a substantial reduction in carbon emissions due to the increase in green finance. In addition, Ghosh (2018) found that green bonds contribute to reducing carbon emissions in wealthy nations. The findings also show that green bonds support developing and maintaining climate-friendly initiatives and a green energy economy. Shen et al. (2021) examine how green investments affect CO_2 emissions and suggest that green investments can improve environmental performance in China through public-private partnerships. Moreover, Huo et al. (2022) suggest that green finance promotes clean energy consumption, and its geographical effects can contribute to controlling energy usage in nearby cities, ultimately resulting in carbon reduction. Similarly, N.

Ahmed et al. (2022) documented that green bonds significantly mitigate CO2 emissions by financing green energy in ASEAN countries.

Furthermore, numerous studies have focused on the improving effect of green finance on green economic growth. For instance, Mohd and Kaushal (2018) emphasise the significance of green finance in promoting green economic growth. They contend that green finance functions as a crucial financial vehicle to bolster efforts aimed at diminishing ozone-depleting compounds and emissions of air pollution. H. Zhang et al. (2022) highlight that green finance plays a crucial role in supporting green projects in these areas, thus promoting sustainable development. It has also been demonstrated that green finance lowers carbon in G7 countries from 1995 to 2019 (Sharif et al., 2022) and mitigates the overuse of natural resources in OECD nations (Gu et al., 2023). However, some scholars hold different views on the relationship between green finance and green economic growth. For example, green finance has an enhancing effect on carbon emission intensity in China through structural transformation (Gan & Voda, 2023), which is detrimental to green economic growth. Besides, there is a U-shaped relationship between green finance and green economic growth in Chinese provinces (J. Zhang et al., 2022).

In summary, while many scholars advocate for the role of green finance in promoting green development, others hold opposing views. Therefore, conflicting findings exist regarding the impact of green finance on green economic growth. The gap needs to be fulfilled in this study by employing developed nations, as they have experienced serious environmental pollution and shifted to green development through green financial policies, such as green bonds.

2.7 Mediating Role of Industrial Structure Upgrading

As discussed earlier, existing studies have substantiated the significance of green finance in bolstering green economic growth (Gu et al., 2023; Sharif et al., 2022). Research has also examined the relationship between green finance and industrial structure upgrading, as well as the interaction between industrial structure upgrading and green economic growth.

On the one hand, green finance is recognised as a crucial driver for promoting industrial upgradation by utilising financial mechanisms to facilitate the efficient functioning and progress of green enterprises. For instance, Cui et al. (2024) argue that green finance employs financial mechanisms to effectively promote green industries and encourage consumers to engage in environmentally friendly consumption. Similarly, as highlighted by Lv et al. (2021), the primary goals of green finance encompass the conscientious management and conservation of the environment. Their findings emphasise the efficacy of green financing in redirecting cash from polluting industries to ecologically friendly industries. In addition, Nur Utomo et al. (2020) provide detailed explanations of the unique strategies employed by green finance to support and promote industrial upgrading. They recognise mechanisms such as green finance and green bonds as crucial in this process.

The prudent distribution of funds and other operations of green finance are crucial for the sustained advancement of industrial policy. For example, X. Wang and Q. Wang (2021) assert that green finance enhances industrial upgrading through the optimisation of energy structures and the stimulation of innovation. In particular, China's primary and secondary sectors are less affected by green finance. However, significant growth was noticed in the tertiary industry. The unique impact on this sector highlights the subtle function of green finance in supporting the upgrading of industrial structures, especially in the service-orientated tertiary industry. This, in turn, facilitates a wider restructuring of the industrial landscape.

On the other side, studies have also shown that the upgrading of industrial structures promotes economic growth and environmental protection, both of which are essential for green economic growth. For instance, Peneder (2003) emphasises the significance of industrial structure in the economic growth of 28 OECD countries and explains how the income elasticity of demand and structural bonuses contribute to fostering economic growth. The findings highlight the significance of upgrading industries to improve economic growth. Furthermore, it has been found that Pakistan's industrialisation enables people to spend more income on their livelihoods through employment generation and increased income levels, hence improving environmental health (Godil et al., 2021). These findings indicate that industrial development has the potential to effectively promote both economic and environmental development.

In summary, previous studies have emphasised the positive effects of green finance and industrial structure upgrading on green economic growth. Additionally, they have confirmed that industrial structures are upgraded by green finance (Gu et al., 2023; Lv et al., 2021; Mehmood et al., 2024). As a result, industrial structure upgrading may mediate the relationship between green finance and green economic growth. Besides, early studies have found that the upgrading of industrial structures acts as a mediator in the interaction between other variables. For instance, Jiang and Wang (2022) discovered that the upgrading of industrial structures partially mediates the connection between biased technological change in forestry and the forestry economy. This indicates a broader applicability of industrial structure upgrading as a mediating factor. Nevertheless, no studies have investigated its mediating role in the link between green finance and green economic growth. Consequently, it is necessary to fill this gap regarding whether industrial structure upgrading mediates the impact of green finance on green economic growth, which would provide deeper insights into the mechanisms driving green economic growth. Hence, further research is required to clarify the role of industrial structure upgrading in mediating the relationship between green finance and green economic growth.

2.8 Mediating Role of Green Technology Innovation

The contribution of green finance to promoting green economic growth has been substantiated by numerous previous studies (Latif et al., 2022; H. Zhang et al., 2022). Scholars have also investigated the relationship between green finance and green technology innovation, as well as the link between green technology innovation and green economic growth, as presented in the following:

On the one hand, green financial instruments, such as green funds and insurance, play a crucial role in directing civilian investments into clean production sectors, thus promoting green innovation. According to Chang et al. (2019), green finance reduces funding for enterprises with high energy use and emissions, discouraging unsustainable behaviours and promoting a favourable climate for green innovation.

On the other hand, the connection between green technology innovation and green economic growth has also been the subject of extensive empirical investigation by academics. For instance, F. Wang et al. (2023) demonstrate how industrialised nations achieve superior environmental quality by employing modern technologies that effectively reduce pollutants and improve environmental conditions. Likewise, Sharma et al. (2021) documented that green technology innovation mitigates pollution and environmental harm by developing and implementing advanced technology, methods, and materials specifically tailored for environmental protection. Green technology innovation serves to achieve equilibrium by aligning economic growth with environmental preservation, which is a crucial aspect of sustainable development (Ikram et al., 2021).

In general, green finance stimulates green innovation of enterprises in both developed and developing nations by substantially alleviating financial constraints (Chang et al., 2019; Deng et al., 2024; H. Huang et al., 2022; Q. Wang et al., 2022). Meanwhile, green innovation contributes to green economic growth in wealthy and poor nations by aligning economic growth with environmental preservation (Deng et al., 2024; Ikram et al., 2021). Hence, green technology innovation may serve as a mediator between green finance and green economic growth.

Furthermore, previous studies have found that green technology innovation plays a mediating role in various other situations. For instance, Yang et al. (2020) discovered that green technology acts as a mediator between environmental legislation and carbon intensity. Moreover, Hao et al. (2023) showed that green technology innovation acts as a mediator between digitalisation and green economic growth. However, no studies have focused on it as a mediator in the relationship between green finance and green economic growth. The gap in the mediating role of green technology innovation is not well studied and requires further investigation. Hence, there is a need to fully comprehend the gap in the mediating effect of green technology innovation on the relationship between green finance and green economic growth. By addressing the gap, this study provides a more profound comprehension of the mechanisms that drive green economic growth.

2.9 Gaps in the literature

This study's review of the literature reveals that divergent views exist among academics regarding the link between green finance and green development. For instance, green finance promotes green economic growth in Belt and Road Initiative member countries as well as in G20 economies (Ma et al., 2023; Zhang et al., 2021). Nevertheless, Gan and Voda (2023) argue that green finance exacerbates carbon emission intensity in China through structural transformation, thereby impeding green economic growth. Hence, the first gap identified in this research is the conflicting findings concerning the impact of green finance on green economic growth. If green finance has a significant contribution to green economic growth, this is crucial for accelerating the green transition's realisation and opening up a novel path for this shift. Consequently, this study aims to find out the influence of green finance on green economic growth in developed nations.

Furthermore, if there is a significant relationship between green finance and green economic growth, the transmission mechanism warrants attention. Understanding the impact of green finance on green economic growth could provide insight into how green finance affects green economic growth, which is essential to effectively achieving green economic growth. It has been found that green finance has a positive impact on the upgrading of industrial structures in China by supplying the required funding (Y. Huang et al., 2022; Zhang, 2023; Zhao et al., 2024). Mean, industrial structure upgrading could enhance green economic growth in South Asia and China (Fang et al., 2022; Xu & Zhou, 2023; Zhu et al., 2019).

Prior studies have also regarded industrial structure upgrading as a mediator in the relationship between technological change and the forestry economy and between financial development and carbon emissions (Jiang & Wang, 2022). But no studies have investigated its mediating role in the link between green finance and green economic growth. Hence, the second gap lies in determining whether industrial structure upgrading mediates the impact of green finance on green economic growth. Further research into the mediating effect of industrial structure upgrading in the link between green finance and green economic growth is warranted. This might open up a new perspective to mediate the enhanced impact of green finance on green economic growth through industrial structural upgrading.

In addition, green finance stimulates green innovation of enterprises in both developed and developing nations by substantially alleviating financial constraints (Deng et al., 2024; H. Huang et al., 2022; Q. Wang et al., 2022). Meanwhile, green innovation contributes to green economic growth in wealthy and poor nations by aligning economic growth with environmental preservation (Deng et al., 2024; Ikram et al., 2021). Previous research also uses green technology innovation as a mediator on the impact of digitalisation on green economic growth (Hao et al., 2023). However, no studies have focused on it as a mediator in the relationship between green finance and green economic growth. As a result, the third gap pertains to the mediating role of green technology innovation in the impact of green finance on green economic growth. By updating the industrial structures, this may create a new way to mediate the increased influence of green financing on green economic growth.

2.10 Supporting Theories

This section aims to provide a detailed explanation of the fundamental theories that serve as a foundation for the development of hypotheses. These theories include the Green Finance Theory, Porter Hypothesis Theory, and Industrial Diffusion Theory. In the subsequent sections, these theories are discussed in relation to the link between green finance and green economic growth, as well as the mediating roles played by industrial structure upgrading and green technology innovation.

2.10.1 Green Finance Theory

"Green finance" has undergone substantial development over the decades, originating in the 1970s. Initially, in 1974, the Federal Republic of Germany established an "Eco Bank" that focused on environmental protection. The "Eco Bank" was the pioneer institution dedicated to providing specialised loans for environmental projects, particularly those that are usually not supported by traditional banks (Wei et al., 2022). This event marked the beginning of organised financial assistance for environmental sustainability in the banking industry, establishing the foundation for a worldwide movement to include environmental factors in financial projects.

Subsequently, in 2002, the introduction of the Equator Principles marked a significant milestone in the international banking sector. The corporate lending guideline sought to establish a uniform method for assessing the social and environmental effects of a project prior to making a financial investment (Lui, 2015). The Equator Principles signify a significant advancement in using financial leverage to advance social responsibility and ecological stewardship, establishing a precedent for global banks to integrate these factors into their lending procedures.

The ratification of the Kyoto Protocol in 1997 intensified the worldwide emphasis on green finance. The international convention highlighted the importance of countries pledging to decrease greenhouse gas emissions, thus establishing environmental sustainability as a crucial economic concern (Chen & Wang, 2012). As a result, green finance has become a crucial tool for countries seeking to transition their economic development towards sustainability. The concept of the Green Finance Theory emphasises the significance of attaining sustainable economic and social development by incorporating environmental preservation and ecological equilibrium into economic endeavours. Currently, there is a significant focus on green finance, especially in the banking industry and in the departments of banks that deal with "green credit." This emphasis is an obvious sign of a wider pattern in which financial institutions have a crucial role in advancing environmental sustainability by implementing specific lending policies. Green finance must continue to be developed in order to facilitate a shift towards more sustainable economic models, guaranteeing that financial systems make a positive contribution to the preservation of the environment and societal well-being.

Green finance is a crucial financial strategy that aims to promote the development of environmentally friendly industries and green activities, therefore supporting green development. The fundamental financial characteristics comprise several essential components. Firstly, the capital accumulation function of green finance involves pooling funds by creating green financial instruments and products, which allows for the conversion of savings income into investment (Jin et al., 2021). Secondly, the role of investment direction requires financial institutions to channel capital toward green initiatives, hence strengthening their ability to amass resources that can be converted into investment capital (Chen & Chen, 2021). Thirdly, the resource integration role entails redirecting capital towards green projects, resulting in improved efficiency in the use of labour, land, and other resources, thereby promoting economic growth (Wang & Zhi, 2016). Given the risks involved in green industry, green finance is essential for reducing risk in the financial system. This transfer induces risk-averse investors to transition from conventional businesses to new green sectors, therefore mitigating risks and evaluating potential opportunities (Qi & Qi, 2020).

The Green Finance Theory is chosen as an important guiding theory of this research, as it clearly states the main content and goals of green finance and promotes a green economy (Yang et al., 2021). This theory advocates for comprehensively evaluating a project's potential environmental effects before providing financial support. Indeed, green finance is a crucial instrument for sustainable, long-term economic expansion by integrating financial activities with environmental conservation. As a result, the Green Finance Theory encourages financial institutions to provide targeted funds to green projects based on green environmental policies, thereby promoting the green transformation of social production activities. These green activities will reduce carbon emissions, mitigate climate change, and realise the harmonisation of human development with resources and the environment, ultimately contributing to green economic growth. Therefore, the goals of the Green Finance Theory are consistent with green economic growth, which commits to coordinated development of the economy, society, environment, and resources. The Green Finance Theory posits that green finance has the potential to significantly facilitate a green economy.

In summary, the Green Finance Theory proposes that more environmental benefits are obtained by providing green financial funds to eco-friendly projects, rather than focusing only on economic benefits as in traditional finance. Hence, the Green Finance Theory offers essential theoretical foundations for examining the effect of green finance on green economic growth, serving as a guiding principle in the context of green finance and green economic growth. It theoretically argues the potential positive impact of green finance in this paper and supports the relevant hypothesis of the link between green finance and green economic growth.

2.10.2 Industrial Diffusion Theory

Rostow initially developed the Industrial Diffusion Theory in 1960. In his seminal work, he outlined five stages of development and argued that transitioning the economy from agriculture to industry would facilitate the spread of economic growth across the entire country (Rostow, 1960). Simultaneously, he categorised the industrial sectors of the national economy into three groups based on their respective contributions to the economic growth of each country: primary growth sectors, complementary growth sectors, and derived growth sectors. The primary growth sector, referred to as a leading sector, has a high growth rate and propels the advancement of the national economy. He specifically highlighted the crucial significance of the dominant industry sector in driving economic growth. He held the belief that selecting and establishing the right leading industry are fundamental prerequisites for economic growth and advancement. Furthermore, he emphasised that the rapid expansion of the leading industry sector is the determining factor for the continued progress of the economy at every stage of its development.

The impacts in Industrial Diffusion Theory can be categorised into three types: the backward effect, side effect, and forward effect, all of which are caused by the leading industry. The backward effect pertains to the effect of the development of the dominant industry sector on the industry sectors that provide inputs to it. The term “side effect” pertains to the economic phenomenon where the leading industry positively impacts the economic optimisation of the surrounding region. The rapid growth of the leading industry resulted in many changes in its surrounding development environment, hence facilitating the broader advancement of the regional economy. The forward effect is an economic phenomenon characterised by the stimulation of new industries as a result of the growth and advancement of a leading industry.

Moreover, it argues that transitioning the economy from agriculture to industry would facilitate the spread of economic growth throughout the entire country (Piętak, 2014). This highlights how upgrading industrial structures from primary to secondary industries effectively stimulates economic growth. In 1971, Rostow further proposed an advanced stage of economic growth, characterised by enhancements in the standard of goods and services. He contended that high mass consumption and the aspiration for a better quality of life play crucial roles in fostering economic development, as they can stimulate the growth of additional industries and contribute to socio-economic development.

According to Industrial Diffusion Theory, the evolution of economic development stages is characterised by a shift in the leading industrial sector. This shift starts in agriculture, moves towards industry, and eventually transitions to a focus on high-quality, high-service industries. This shift in focus drives the growth of other industries and ultimately leads to overall economic development. Industrial Diffusion Theory confirms that the upgrading of industrial structures encompassing primary, secondary, and tertiary industries serves as a key driving force of regional economic development. The inputs and outputs of different industrial sectors vary considerably, with the tertiary industry demonstrating higher production efficiency (Piesse & Thirtle, 1997).

Therefore, this study adopts the Industrial Diffusion Theory as a supporting theory to examine the role of industrial structure upgrading in mediating the relationship between green finance and green economic growth. The theory asserts that the rapid expansion of key industrial sectors, along with their diffusion effects and spreading effects, have a significant role in maintaining economic growth throughout time. It states that the improvement of industrial structures contributes to economic development. The upgrading of industrial structures in a country or region involves a shift in the proportion of primary, secondary, and tertiary industries. This shift in leading industries will ultimately lead to changes in input industries and economic growth. In addition, Industrial Diffusion Theory posits that the upgrading of industrial structures has a direct impact on the economic prosperity of a region. Especially the tertiary industry, which mostly encompasses software, information technology, and service sectors, exhibits not only the highest level of productivity but also the lowest amount of pollution. While the primary industry and secondary industry are characterised by high resource consumption and pollution. Hence, the upgrading of industrial structures benefits green economic growth.

In the meantime, the upgrading of industrial structures could be advanced by the provision of green financial support. Specifically, the tertiary sector is well-suited to align with green finance policies due to its minimal impact on pollution. Thus, green finance has been found to assist in the appropriate upgrading of the industrial structure through various strategies, including green credit and green bonds (Nur Utomo et al., 2020).

2.10.3 Porter Hypothesis Theory

Early neoclassical economics posited that environmental protection policies would lead to higher production costs for enterprises, reduce environmental pollution, and impose additional expenses for environmental governance. As a result, this would offset the advantages of environmental preservation for society and hinder economic growth (Jorgenson & Wilcoxen, 1990). Nevertheless, Porter and Linde presented a contrasting perspective. Their analysis proposed that the implementation of effective environmental regulations could independently foster the "innovation compensation" effect, offsetting the costs of environmental governance. This, in turn, could lead to environmental benefits by enhancing productivity and fostering international competitiveness (Porter & Van der Linde, 1995).

Porter and Vender provided further explanation of how effective environmental protection policies might increase innovation and, thereby, enhance the pathway to achieving competitiveness. They argued that the most effective way to stimulate economic growth through environmental preservation regulations is to encourage businesses to adopt cutting-edge technologies. Due to the constant change in market demand, factor input mix, and production technology, it is not appropriate to use the static game assumption to analyse the effectiveness of environmental regulation. Therefore, a dynamic perspective must be used to examine how environmental regulations affect the economy. While environmental regulations may initially impose additional costs or diminish earnings for corporations, they ultimately serve as a catalyst for inducing and motivating enterprises to prioritise environmental concerns, despite the temporary competitive disadvantage they may experience. Nevertheless, the technological advancements made by corporations will not only gain an initial advantage by being the first to innovate but also improve their market share and competitiveness in the long term.

While environmental regulations may initially impose additional costs or reduced profits for companies, they ultimately serve as a catalyst for inducing and motivating enterprises to prioritise environmental concerns, despite the temporary competitive disadvantage they may experience. However, the technological innovation of companies will not only obtain a "first-mover advantage" through the "innovation compensation" effect but also enhance the market share and competitiveness of enterprises in the long run (Porter & Van der Linde, 1995). The Porter Hypothesis Theory asserts that a well-designed environmental policy will promote technological innovation activities and the competitiveness of companies. There are three factors that contribute to this: (i) environmental policies encourage businesses to improve their resource usage efficiency and guide them towards technological innovation; (ii) it prompts companies to focus on environmental data indicators and increase their environmental awareness; (iii) it changes the traditional competitive landscape, allowing companies that invest in environmental protection to gain a better position.

Hence, the Porter Hypothesis Theory is considered a supporting theory in this study as it seeks to investigate how green finance and green technology innovation contribute to the improvement of green economic growth. There are three specific arguments that support the choice of this theory as the guiding framework.

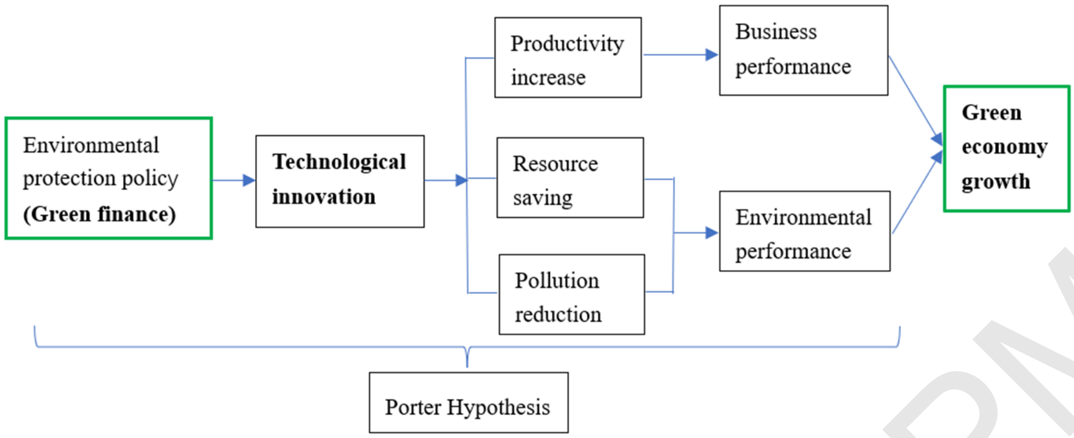

Figure 2.2: Application of the Porter Hypothesis in the path of green finance's impact on green economic growth
(Source: Compiled by the author)

Firstly, the Porter Hypothesis Theory focuses on the impact of environmental protection legislation on the technical innovation and competitiveness of companies. This theory seems relevant in the context of this study. Green finance policies are a new type of environmental legislation that aims to tackle environmental issues and direct companies towards making ecologically responsible choices by distributing funding through government regulations. It is a distinct form of environmental control in the financial system (Su et al., 2022). Figure 2.2 demonstrates that the Porter Hypothesis suggests that environmental protection regulations, such as green finance initiatives, encourage technological innovation in companies, resulting in long-term "innovative compensation." This innovation improves production efficiency, conserves resources, and minimises environmental damage, closely fitting with the goals of green economic growth.

Secondly, adhering to the Porter Hypothesis, green finance expedites the advancement of green technology innovation within companies, hence improving operational effectiveness, diminishing ecological contamination, and promoting sustainable economic growth. This theory suggests that environmental measures might result in simultaneous advantages for the environment, economy, and technology by designing and implementing proper policies. This notion serves as a fundamental basis for formulating efficient green finance policies by governmental entities.

Thirdly, based on the Porter Hypothesis, the punitive actions of green finance initially result in an increase in production costs for companies that pollute the environment. If firms do not instantly experience the benefits of green technology innovation, they may lose the incentive to innovate in production and pollution control. This could lead to a decrease in investment in R&D. Nevertheless, despite the initial financial constraints, green finance ultimately has a positive impact by forcing businesses to invest in technology that safeguards the environment and improves their long-term environmental management efforts. In order to obtain financing for sustainable economic growth, companies must implement green production methods, enhance investments in R&D, minimise pollutant emissions, and enhance productivity and resource efficiency. As a result, polluting companies are motivated by green finance to create ecologically sustainable methods and improve their productivity in the future.

The Porter Hypothesis holds significant theoretical and practical implications for evaluating whether green finance, as an environmental policy designed to foster innovation in green technology, aligns with its principles. The study relies on Porter's hypothesis as a fundamental theory, which supports its development and creation and confirms the study's intrinsic rationality and scientific validity.

2.11 Hypotheses Development

2.11.1 Green Finance and Green Economic Growth

Theoretically, green economic growth emphasises the consideration of the balance between human beings and nature in the process of sustainable development. That is the reason why many governments have adopted a new path of economic development, switching from the crude economic growth model to the green development model. Simultaneously, the Green Finance Theory seeks to save the environment by endorsing green initiatives and ultimately achieving sustainable growth, along with the aforementioned objective. This theory advocates for comprehensively evaluating a project's potential social and environmental effects before providing financial support. Therefore, green finance serves as a crucial tool for achieving sustainable economic growth by integrating financial activities with environmental conservation. The Green Finance Theory posits that green finance has the potential to significantly contribute to the growth of the green economy.

Furthermore, numerous studies have also concentrated on the influence of green finance on green economic growth, highlighting two primary mechanisms. First, the catalytic role of green finance in green economic growth hinges significantly on targeted financial support for green activities. For example, green bonds play a crucial role in reducing carbon dioxide by funding the development and maintenance of climate-friendly activities (Ghosh, 2018). Green economic growth could be achieved by providing financial support from green finance, thereby lowering ozone and air pollution levels (Mohd & Kaushal, 2018). In developing countries, green finance strengthens green economic growth by supporting green initiatives (H. Zhang et al., 2022). Environmental finance also provides financial assistance for projects that protect the environment, reduce pollution, save resources, and carry out other eco-friendly actions (Latif et al., 2022). Notably, green finance has been shown to mitigate environmental degradation in G7 countries (Sharif et al., 2022).

Second, studies have examined the impact from a risk management perspective. Financial institutions primarily depend on comprehensive risk management strategies to reduce the investment risk associated with green projects, thereby ensuring their sustainability (Chen & Chen, 2021). Overall, green finance provides financial support for eco-friendly projects, which not only improves economic benefits but also enhances environmental benefits. Based on the above-mentioned literature, the following hypothesis is proposed:

H1: Green finance has a positive effect on green economic growth.

2.11.2 Mediating Effect of Industrial Structure Upgrading

Industrial Diffusion Theory states that the evolution of economic development stages is characterised by a change in the leading industrial sector, moving from agriculture to industry and eventually transitioning to the pursuit of high-quality, high-service industries. This shift ultimately fosters overall economic development. Industrial diffusion theory affirms that the upgrading of industrial structures encompassing primary, secondary, and tertiary industries serve as a key driving force of regional economic development. The upgrading of industrial structures contributes to environmental protection and resource conservation by reducing pollution and consumption, hence promoting green economic growth. At the same time, the upgrading of industrial structures could be achieved through the provision of green financial support. Specifically, the tertiary sector is more capable of aligning with green financing policies due to its minimal contribution to pollution.

Theoretically, there are two fundamental methods by which industrial structure upgrading could mediate the relationship between green finance and green economic growth, as depicted in Figure 2.3.

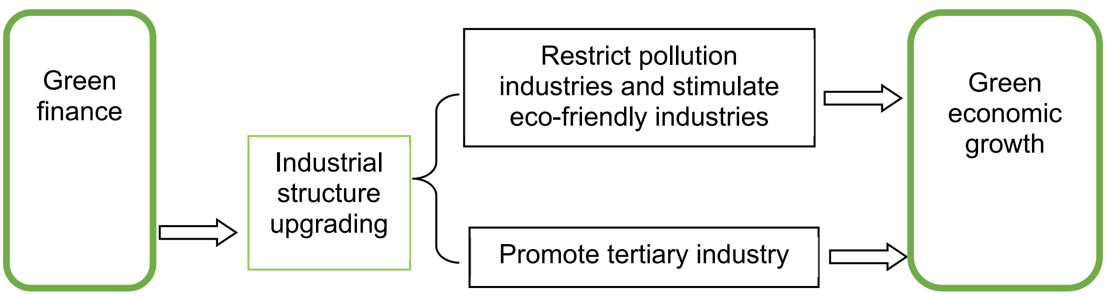

Figure 2.3: The mediating effect of industrial structure upgrading
(Source: Drawn by the author)

Firstly, green finance imposes restrictions on polluting projects while simultaneously encouraging eco-friendly projects. This approach is designed to promote environmental sustainability and foster green economic growth by facilitating the upgrade of industrial structures. Green finance provides financial assistance to green projects and helps financial institutions distinguish between polluting projects and eco-friendly projects through the implementation of green financial policies. Given that the majority of energy consumption and carbon emissions originate from the secondary industry, upgrading industrial structures has significant potential to reduce carbon emissions (Ma et al., 2019). At the same time, such upgrades involve a decrease in industries that cause pollution and a rise in industries that promote environmental sustainability. This shift is beneficial for fostering green economic growth. Consequently, green finance policies influence the financing landscape by curtailing support for polluting industries and enhancing opportunities for eco-friendly enterprises. This shift ultimately contributes to the growth of the green economy by limiting environmentally detrimental industries and promoting sustainable development.

Secondly, green finance promotes tertiary industry, which is characterised by the highest added value and lowest pollution, thus contributing to green economic growth. Green finance diverts financial resources from the primary and secondary industries to the tertiary industry, resulting in the upgrading of industrial structures. The primary and secondary sectors exhibit significant levels of consumption, pollution, and reliance on resources, with the secondary industry being more prominent in these aspects. In contrast to them, the tertiary industry, which mostly consists of software, information technology, and service sectors, has the highest value added and the lowest pollution levels. It also effortlessly fulfils environmental protection regulations. Simultaneously, the process of upgrading industrial structures entails a decrease in the presence of industries that cause pollution and an expansion in the tertiary sector, which has the highest economic value and the lowest environmental impact. This shift is beneficial for promoting sustainable economic growth.

In terms of empirical findings, related empirical studies have verified the contribution of green finance to industrial structure upgrading as well as the positive effect of green finance and industrial structure upgrading on green economic growth, which are described below.

Several studies have focused on analysing the effect of green finance on industrial structure upgrading. Green finance primarily seeks to promote responsible environmental management and preservation by effectively reallocating revenues from polluting industries to ecologically sustainable ones (Lv et al., 2021). Green finance promotes the necessary improvement of industrial structures by employing several approaches, such as green loans and green bonds (Nur Utomo et al., 2020). Green finance has a positive impact on the upgrading of industrial structures by supplying the required funding (Y. Huang et al., 2022).

Furthermore, the process of upgrading the industrial structure is crucial to promoting a green economy. The main catalyst for decreasing carbon emissions is the shift of industrial structures from heavy industries to technology and services industries (Green & Stern, 2017). For instance, Pakistan's carbon intensity experienced a decline as its green industry underwent change from 1975 to 2020 (Mehmood et al., 2024). The transition from primary and secondary sectors to tertiary sectors enhances the efficiency of green growth (Zhu et al., 2019). In addition, a reduction in pollutants can be facilitated by the decreasing proportion of the secondary industry and the increasing proportion of the financial business (Jing et al., 2021). Industrial structural upgrading has a direct impact on promoting green development as well as indirect benefits through geographical spillover (Xu & Zhou, 2023).

Moreover, green finance plays a substantial role in fostering green economic growth. The green credit policy improves the efficiency of allocating financial resources by moving funding from high-pollution firms to environmental protection industries (Al-Qudah et al., 2023). This leads to increased production and improved environmental quality (Baloch et al., 2020). Environmental finance offers financial support for environmentally beneficial initiatives and endeavours (Latif et al., 2022). Green finance provides essential financial services for the advancement of environmentally friendly economic growth through the use of various innovative financial arrangements (Geng et al., 2023).

In general, green finance categorises industries and supports the upgrading of traditional industries, ultimately driving green economic growth. Previous studies have also found that industrial structure upgrading plays a role in mediating different relationships. For example, it mediates the relationship between biased technological change in the forestry sector and the high-quality development of the forestry economy, between green technology innovation and carbon emissions, and between financial development and carbon emissions (Feng & Wu, 2022; Gao et al., 2022; Jiang & Wang, 2022). This study suggests that industrial structure upgrading has a mediating function in the relationship between green finance and green economic growth. Therefore, based on the above-mentioned literature, the following hypothesis is proposed:

H2: Industrial structure upgrading positively mediates the relationship between green finance and green economic growth.

2.11.3 Mediating Effect of Green Technology Innovation

According to Porter Hypothesis Theory, implementing effective environmental regulation methods could serve as a signal that resource allocation is inefficient and technology needs to be improved. This can independently foster the "innovation compensation" effect, offset the costs of environmental governance, and ultimately lead to environmental benefits by increasing productivity. While environmental regulations may initially impose additional expenses on corporations, resulting in a temporary competitive disadvantage, they ultimately serve to restrict and control their operations. In the long term, organisations' technical innovation will not only compensate for the costs incurred by following others and gain an advantage by being the first to introduce innovations, but also improve their market share and competitiveness (Porter & Van der Linde, 1995).

Even though Porter Hypothesis Theory mainly studies the impact of environmental protection policy on the technological innovation and competitiveness of enterprises. However, it also holds significant relevance in guiding the relationship between green finance, green technology innovation, and green economic growth. Green finance policy is a market-driven regulation of the funding and investment arrangements for green enterprises that operates independently of the government. It represents a form of environmental regulation that extends and enhances traditional environmental legislation within the financial market, serving as an innovative advancement of these regulations (Su et al., 2022). Therefore, the support of green finance can boost the invention of firms in green technology, thereby promoting their activities in green innovation.

Furthermore, the improvement of green technology innovation by enterprises significantly contributes to green economy in several ways. Green technology innovation helps decrease the consumption of fossil energy by developing new equipment, new processes, and new materials, such as the use of clean energy (Cheng & Yao, 2021). The implementation of these green innovations greatly contributes to environmental preservation and the efficient utilisation of resources. Additionally, the innovation of green technology also enhances productivity and offsets the costs associated with R&D, thereby fostering sustainable economic growth. Therefore, green finance has the potential to stimulate green economic growth by enhancing the development of innovative green technologies, as seen in Figure 2.4.

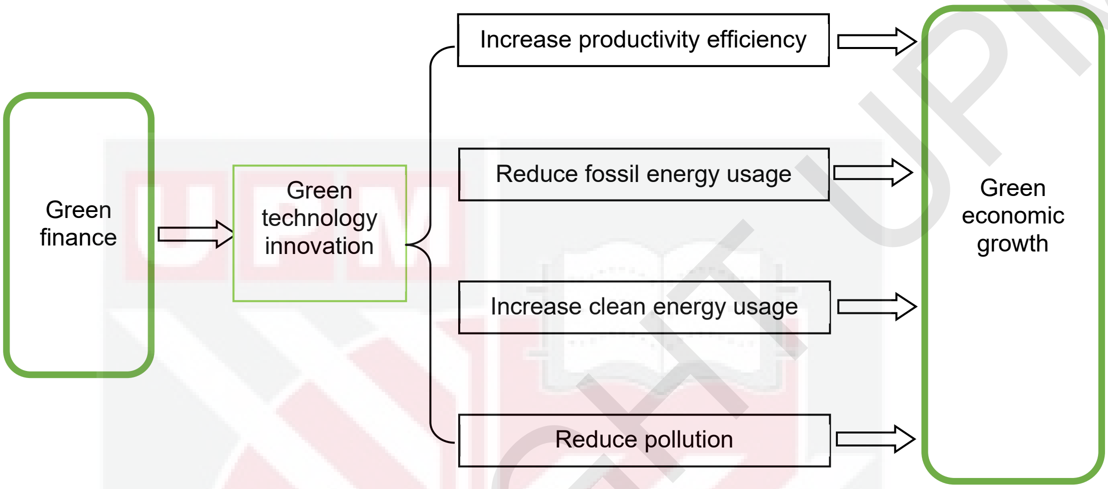

Figure 2.4: The mediating effect of green technology innovation
(Source: Drawn by the author)

From the perspective of the empirical results, related studies have verified the positive effect of green finance on green technology innovation as well as the contributions of green finance and green technology innovation to green economic growth, as described below.

Firstly, the beneficial impact of green finance on green technology innovation. Green finance primarily exerts a positive impact on the innovation of green technology by restricting funding for energy-intensive and highly polluting businesses, therefore encouraging innovation in environmentally friendly industries (Chang et al., 2019). Notably, green finance policies substantially alleviate financial constraints on green innovation, albeit with limited impact on private firms, thus impeding green innovation within such firms (C.-H. Yu et al., 2021). To facilitate an effective transition towards renewable energy and sustainable development goals, green finance serves as a pivotal funding mechanism for green technology initiatives (Madaleno et al., 2022).

Secondly, followed by the contribution of green technology innovation to green economic growth. Green technology innovation plays a crucial role in promoting green economic growth by combining environmental conservation requirements with technological innovation (Sun et al., 2022). Green innovation aims to reduce pollution and environmental degradation by using advanced technology, processes, and materials (Sharma et al., 2021). It ensures that technical breakthroughs have minimal negative effects on the environment (Liu et al., 2021). Moreover, the advancement of green technology has a vital role in achieving a balance between economic progress and the protection of the environment, thereby promoting sustainable development (Ikram et al., 2021).

Thirdly, green finance also has a positive effect on green economic growth. Green credit programs shift funds from high polluters to environmental industries (Al-Qudah et al., 2023); in turn, this increases productivity as well as the quality of the environment (Baloch et al., 2020). Moreover, environmental finance plays a crucial role in providing financial assistance for environmentally sustainable projects and efforts, thereby enhancing the growth of green economic growth (Latif et al., 2022). By utilising cutting-edge financial processes, green finance efficiently stimulates the growth of green economic activities (Geng et al., 2023).

In summary, as an environmental protection policy, green finance accelerates green technology innovation in enterprises by providing financial support. This, in turn, enhances production efficiency, promotes resource conservation, and reduces environmental pollution, thereby advancing green economic growth. Other studies have also discovered that green technology innovation acts as a mediator in the relationship between other variables. For instance, green technology serves as a mediator in mitigating the effects of environmental regulations on carbon intensity, as demonstrated by Yang et al. (2020). Moreover, green technology innovation plays a mediating role in the relationship between digitalisation and green economic growth, as digital technologies positively affect the direction of green innovation, ultimately relieving environmental pressure (Hao et al., 2023). Hence, this study argues that green technology innovation acts as a mediator between green finance and economic growth. Based on the above-mentioned literature, the following hypothesis is proposed:

H3: Green technology innovation positively mediates the relationship between green finance and green economic growth.

2.12 Conceptual Framework

This study has examined and consolidated the past literature on green finance, industrial structure upgrading, green technology innovation, and green economic growth, which are fundamental to this research. Then the pertinent research hypotheses are derived from relevant literature and supported theories, including the Green Finance Theory, the Industrial Diffusion Theory, and the Porter Hypothesis Theory. Finally, this study puts forward the precise conceptual framework based on the above analysis, represented in Figure 2.5.

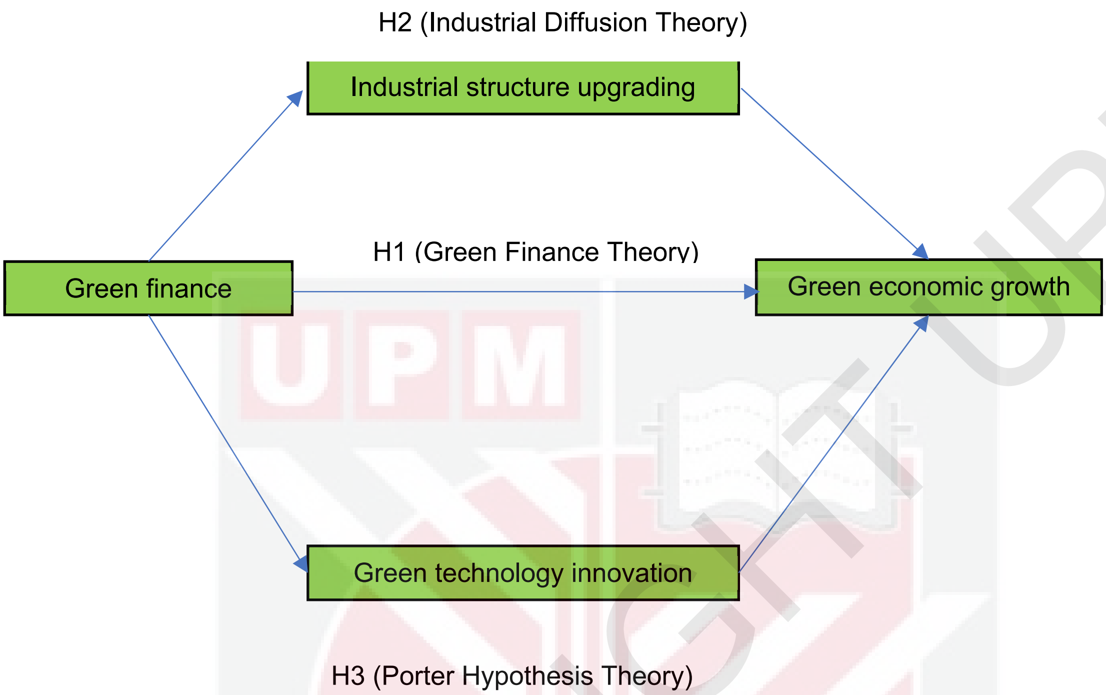

Figure 2.5: Conceptual framework of this research
(Source: Drawn by the author)

Specifically, Hypothesis 1 argues that green finance has a positive impact on green economic growth. Theoretically, the Green Finance Theory encourages financial institutions to provide targeted funds to green projects based on green environmental policies, which is beneficial to environmental protection and carbon reduction. The goals of the Green Finance Theory are consistent with green economic growth. Relevant research has also confirmed that green finance enhances green development by supporting green projects in both wealthy and poor nations (Afzal et al., 2022; Zhang et al., 2021).

Furthermore, Hypothesis 2 states that industrial structure upgrading positively mediates the influence of green finance on green economic growth. This may be because green finance distinguishes between green industry and pollution industry through green financial policy, which will be beneficial to the upgrading of industrial structures. Ultimately, this process contributes to green economic growth. Supporting studies have found that green finance facilitates the upgrading of industrial structures in China by supplying the required funding (Y. Huang et al., 2022; Zhang, 2023; Zhao et al., 2024). In addition, industrial structure upgrading could improve environmental and economic benefits based on the Industrial Diffusion Theory, contributing to green economic growth. Related research reveals that industrial structure upgrading could promote green economic growth in South Asia and China (Fang et al., 2022; Xu & Zhou, 2023; Zhu et al., 2019).

Additionally, Hypothesis 3 states that the impact of green finance on green economic growth is strengthened by the mediator of green technology innovation. This is due to the fact that green finance provides financial support for enterprises' green activity, such as green innovation. In turn, the improved green innovation of enterprises would benefit green economic growth by accelerating productivity, clean energy usage, and pollution reduction according to the Porter Hypothesis Theory. Numerous studies find that green finance stimulates green innovation of enterprises in both developed and developing nations by substantially alleviating financial constraints (Deng et al., 2024; H. Huang et al., 2022; Q. Wang et al., 2022). Meanwhile, green innovation contributes to green economic growth in wealthy and poor nations by aligning economic growth with environmental preservation (Deng et al., 2024; Ikram et al., 2021).

2.13 Summary

This chapter has conducted a literature review of green finance, industrial structural upgrading, green technology innovation, green economic growth, and the intrinsic relationships among them. Subsequently, the relevant gaps in the literature are identified, such as the conflicting findings on the impact of green finance on green economic growth and the limited studies on whether industrial structural upgrading and green technology innovation play a mediating role in this impact.

This chapter also seeks to provide a detailed explanation of the fundamental theories that form the basis for the hypotheses in this study. The three fundamental theories comprise the Green Finance Theory, Industrial Diffusion Theory, and Porter Hypothesis Theory. This section does a comprehensive theoretical study and also evaluates empirical findings from the relevant literature. These findings are used to develop the research hypotheses. They are the hypotheses of the promoting effect of green finance on green economic growth and the hypotheses of the mediating roles of industrial structural upgrading and green technology innovation. Finally, this chapter comes up with the conceptual framework of this research.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

This chapter is structured to ensure the meticulous progress of empirical analysis. In Section 3.2, samples are selected from a total of 28 developed countries spanning the years 1995 to 2022. Section 3.3 provides a comprehensive overview of the two primary sources of data, namely the World Bank and the OECD databases. Section 3.4 introduces the data analysis techniques that were employed in this study. The construction of models for objectives 1, 2, and 3 is briefly outlined in Section 3.5, followed by the measurement of variables in Section 3.6.

3.2 Sample Selection

This study employs a panel sample comprising 28 developed countries from 1995 to 2022 to investigate the impact of green finance on green economic growth and the mediating effects of industrial structural upgrading and green technology innovation. The rationale for selecting developed nations rather than developing or least developed countries is as follows:

First, from the perspective of historical development. Wealthy countries have undergone rapid economic advancement along with substantial pollution and have subsequently redirected their attention towards green economic growth. For example, in 2007, the European Investment Bank issued the world's inaugural green bond to support green initiatives and promote renewable energy development as a response to the environmental problem (Nguyen et al., 2021). A relevant study has revealed that developed countries have effectively improved environmental quality, resulting in a substantial decrease in carbon emissions and an enhancement of ecological conditions, such as through the use of advanced technology (F. Wang et al., 2023). In contrast, developing and underdeveloped countries have prioritised economic growth over environmental and resource conservation (S. Khan et al., 2022; Tenaw & Beyene, 2021), making it challenging to balance economic growth and environmental protection.

Second, from a comparative data perspective. Figures 1.1, 1.2, and 1.3 in Section 1.1 illustrate the changes in the growth of GDP per capita and carbon emissions from 1976 to 2022 for developed, developing, and least developed regions. On the one hand, growth in GDP per capita of developing and least developed regions is significantly higher than that of developed ones during this period. On the other hand, carbon emissions in developing and least developed regions continue to rise steadily, whereas carbon emissions in developed nations have gradually declined after peaking at high levels. This comparison highlights that while developing and least developed regions exhibit high levels of economic growth and carbon emissions, industrialised nations show the opposite. Therefore, focusing on a sample of developed countries is more suitable for this research than including developing or least developed economies.

Furthermore, there are 34 developed countries in the world, as outlined in Table 3.1. This classification is based on the World Economic Outlook 2022 issued by the International Monetary Fund (IMF) (Bulíř & Vlček, 2021; Maldonado & Olivo, 2022).

Table 3.1: List of developed countries according to the IMF

Number	Developed nations	Mark	Number	Developed nations	Mark
1	Australia		18	Korea	
2	Austria		19	Latvia	*
3	Belgium		20	Lithuania	*
4	Canada		21	Luxembourg	
5	Cyprus	*	22	Malta	*
6	Czech Republic		23	Netherlands	
7	Denmark		24	New Zealand	
8	Estonia	*	25	Norway	
9	Finland		26	Portugal	
10	France		27	Singapore	*
11	Germany		28	Slovak Republic	
12	Greece		29	Slovenia	
13	Iceland		30	Spain	
14	Ireland		31	Sweden	
15	Israel		32	Switzerland	
16	Italy		33	United Kingdom	
17	Japan		34	United States	

"*" represents the presence of significant missing data

However, the data on green finance and green technology innovation is from the OECD database. Six countries, marked with an asterisk, exhibit significant data gaps. Specifically, Malta lacks sufficient data on green technology innovation; Cyprus and Singapore are not members of OECD nations and do not have relevant data on green finance; Estonia, Latvia, and Lithuania show substantial deficiencies in their green finance statistics.

As a result, the study focuses on a sample of 28 developed countries, excluding the six nations with incomplete data. Figure 3.1 illustrates the geographic boundaries of the selected sample countries (indicated by the blue line), while the yellow areas represent the global map. The 28 developed countries include Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Japan, Korea, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, the United Kingdom, and the United States.

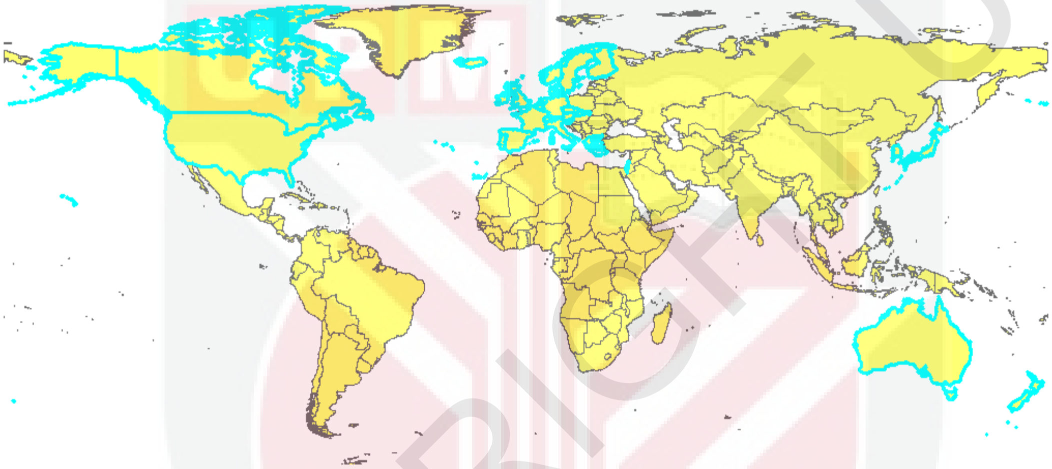

Figure 3.1: Geographical distribution of sample countries

3.3 Sources of Data

The primary source of data for this study is predominantly derived from the World Bank and OECD databases. The World Bank database provides the necessary data on green economic growth, industrial structure upgrading, and control factors. Meanwhile, the OECD database supplies important data on green finance and green technology innovation. In this study, the number of green patents serves as a proxy for one mediator of green technology innovation. Given that the data on green patents is only accessible until 2020, i.e., from 1995 to 2020, this study adopts a linear interpolation and extrapolation strategy of statistical software for data science (Stata) to augment the data for the years 2021 and 2022 based on previous work (Bacon et al., 2018; Kruse et al., 2022; Leasure et al., 2023; Werahera et al., 1995). This strategy is a method of interpolating missing data or extrapolating estimates of future data based on past and present trends (McNown et al., 1995). For instance, Kruse et al. (2022) adopted a linear interpolation and extrapolation strategy to estimate the missing data of policy instruments at the beginning and end of a series. Werahera et al. (1995) demonstrated its feasibility for filling data gaps. Additionally, Leasure et al. (2023) employed Stata's linear interpolation and extrapolation functions to transform annual data estimates into monthly estimates. Consequently, the reliability of the predicted data is well supported by established practices.

The World Bank database is a valuable and comprehensive collection of data offered by one of the major organisations providing financial and technical aid to developing countries worldwide. The World Bank, founded in 1944, consists of 186 member countries and is committed to promoting harmonious development and achieving long-term poverty reduction. The database covers a wide range of fields, such as agriculture, education, energy, transportation, environment, finance, health and nutrition, sanitation, science and technology, rural and urban development, social security and labour protection, community and human settlements, individual and public economy development, macroeconomics, economic growth, and poverty reduction. The World Bank has made its comprehensive data collection available for free, which includes important tools such as the World Development Indicators (WDI) and Global Development Finance (GDF).

Another vital data source is the OECD database. This database is a supranational economic organisation consisting of 38 market economies. It was established in 1961. The OECD was created in 1948 by the USA and Canada to carry out the Marshall Plan for rebuilding Europe after World War II. The membership progressively grew to encompass countries outside of Europe, resulting in its rebranding as the OECD in 1961. The OECD database contains comprehensive data and information for both OECD member countries and certain non-member economies. It covers a wide range of 17 areas, including country accounts, economic indicators, labour, trade, employment, migration, education, energy, health, industry, taxation, tourism, and the environment.

3.4 Data Analysis Technique

3.4.1 Entropy-weighted TOPSIS Method

This research aims to newly construct a comprehensive index for assessing and monitoring green economic growth at the national level. To achieve this, a suitable approach for measuring the index needs to be identified. Currently, there are some common methods for multi-indicator fitting, including the factor score method, the entropy weight method, and TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution).

The first method, the factor score method, transforms multiple highly correlated variables into a few uncorrelated factors and assigns weights to determine the final factor score and ranking (Dang et al., 2022; Velicer, 1976). This method simplifies complex indicators into manageable factors. However, it is unsuitable for panel data analysis, as it does not allow for covariance of unique factors across blocks in linear regression models, potentially leading to qualitative errors in panel studies (Skrondal & Laake, 2001). Then, the second method, the entropy weight approach, uses the degree of variation of each indicator and information entropy to calculate objective weights for each indicator (Yan et al., 2014). Indicators with smaller entropy weights exhibit greater variation and provide more information, resulting in larger assigned weights. This method reduces the influence of subjective factors by considering various indices to assign weights, thus calculating the final fitted value (Lin & Zhou, 2022). Lastly, the TOPSIS approach is a comprehensive evaluation method that utilises raw data information to calculate the distance between the solution and the optimal as well as the worst solutions (Yadav et al., 2018). This technique can fully reflect the degree of proximity of each evaluation solution to the optimal solution, so as to evaluate and rank the various solutions. It effectively reflects the proximity of evaluation solutions to the optimal outcome, aiding in decision-making and ranking (Selvachandran et al., 2018).

In summary, the factor score method is unsuitable for the panel data analysis in this paper due to its potential for qualitative errors. While both the entropy weight method and TOPSIS have their advantages in weighting and decision selection, respectively. Besides, the TOPSIS approach could be further improved by the entropy method, which enables a more objective assessment of weights and decision outcomes (X. Yu et al., 2020). Therefore, this study adopts the entropy-weighted TOPSIS method to evaluate the comprehensive index of green economic growth. The entropy method is used to determine weights, and the TOPSIS approach is subsequently applied for the final evaluation, ensuring a scientific and robust evaluation process.

The calculation technique and its outcomes are outlined below:

1. Build the original matrix.

Firstly, this study constructs the original matrix $(X_{t,j})_{n*m}$, which denotes the value of the j indicator in year t.

2. Forward or reverse processing of data by the entropy method.

Different indicators represent varying implications: for some positive indicators, a higher value is preferable, whereas for certain negative indicators, a lower value is better. Consequently, the next step involves normalizing the data through forward or reverse processing, depending on the nature of each indicator. This ensures a consistent basis for comparison, aligning all indicators in the same directional context for accurate evaluation. For each indicator, if it is positive in nature, then the larger the value of the indicator, the more positive the indicator is for the composite index, the formula for standardization at this point is $X_{t,j}^{-}$=($X_{t,j}$-min $X_{t,j}$) /($maxX_{t,j}$- $minX_{t,j}$); if it is negative in nature, the smaller the value of the indicator, the more favourable the indicator is for the composite index, the formula for standardization is $X_{t,j}^{-}$=(max $X_{t,j}$-$X_{i,j}$) /($maxX_{t,j}$- $minX_{t,j}$).

3. Calculate the proportion of the j indicator in year t:

$$Y_{t,j}=X_{t,j}^{-} / \sum_{t=1}^{n} X_{t,j}^{-} \tag{1}$$

4. Figure out the information entropy value E_j and information utility value d_j of indicator j:

$$E_j=-\frac{1}{\ln n} / \sum_{t=1}^{n} Y_{t,j} \ln Y_{t,j} \tag{2}$$

Where the values of E_j are in the range [0, 1].

$$d_j=1-E_j \tag{3}$$

5. Figure out the weight of indicator j:

The entropy weight method gives weight to each indicator according to the variability of indexes and reduces the interference of subjective factors.

$$W_j=\frac{d_j}{\sum_{t=1}^{n} d_j} \tag{4}$$

6. Figure out the positive and negative ideal solution values by the TOPSIS method:

$$A_{t,j}=W_j X_{t,j}^{-} \tag{5}$$

After calculating the weights of all indicators, the TOPSIS method is used to find out the positive and negative ideal solution values (A^+ and A^-) of the indicators. The positive ideal solution A^+ is the max of A^-, the negative ideal solution A_t^- is the min of $A_{t,j}$.

7. Calculate the distance from each ideal solution to the positive ideal solution and the negative ideal solution.

$$D_t^+ = \sqrt{\sum_{j=1}^{m}(A_t^+ - A_{t,j})^2} \tag{6}$$

$$D_t^- = \sqrt{\sum_{j=1}^{m}(A_t^- - A_{t,j})^2} \tag{7}$$

Where the positive ideal solution A_t^+ is the max of $A_{t,j}$, the negative ideal solution A_t^- is the min of $A_{t,j}$. and positive ideal solution distance and negative ideal solution distance represented as D_t^+ and D_t^- respectively.

8. Calculate the relative proximity of the green economic growth index.

$$C_t = \frac{D_t^-}{(D_t^- + D_t^+)}, \; C_i \subset (0,1) \tag{8}$$

Finally, the relative proximity of the green economic growth index (C_t) is calculated based on the ratio of the distance to the negative ideal solution to the sum of the distance from positive and negative ideal solutions. The relative proximity C_t signifies how close the evaluation object is to the optimal solution: the higher the value, the closer the evaluation object is to the optimal solution.

3.4.2 Descriptive Statistical Analysis

Descriptive statistical analysis uses numerical and graphical tools to organise and explain the features of a specific sample, offering a thorough overview of the raw data (Fisher & Marshall, 2009). It is the initial understanding of the data source before going for further analysis. The analysis usually includes the concentration trend, the degree of dispersion, the frequency distribution of the data, etc. In this study, which uses macroeconomic panel data, the descriptive statistical analysis shows the overall features, such as the mean, standard deviation, variance, minimum, and maximum values for all variables.

3.4.3 Correlation Analysis

After the descriptive statistical analysis of the variables, a correlation analysis is performed to provide a preliminary understanding of the relationships between them. Correlation analysis is used to describe the relationships between variables, with the assumption that quantitative variables have a linear relationship (Twomey & Kroll, 2008). This analysis investigates the potential dependence between phenomena and explores the direction and degree of correlation between specific dependent phenomena. Common techniques for correlation analysis include scatter plots and Pearson's correlation coefficient. A scatter plot is a graph of two variables on the plane of a right-angled coordinate system that shows the general trend of the dependent variable as the independent variable changes (Touchette et al., 1985). While the Pearson correlation coefficient is the most commonly used approach for correlation analysis. This method is based on three fundamental assumptions: (1) the linear relationship between variables; (2) the variables are independent; and (3) the variables are normally distributed (Häne et al., 1993). The correlation coefficient ranges from -1 to +1, reflecting the intensity and direction of the relationship: a value of -1 shows a perfect negative correlation, +1 indicates a perfect positive correlation, and 0 indicates no correlation at all.

3.4.4 Multicollinearity Test

If the correlation coefficients between the variables are relatively high, further multicollinearity testing is necessary to address the multicollinearity problem (Kim, 2019). Multicollinearity occurs when predictor variables have strong or perfect correlations, which can make estimating coefficients (β) as well as interpreting results challenging (Kraha et al., 2012). The specific reasons for the emergence of multicollinearity include the existence of linear relationships or common time trends between explanatory variables, the introduction of lagged variables, etc. (Kim, 2019). Furthermore, the variance inflation factor (VIF) is widely used to assess the degree of multicollinearity in a multiple linear regression model. VIF represents the ratio of the variance of an estimated coefficient with multicollinearity to the variance of an estimated coefficient without multicollinearity (Cheng et al., 2022). Essentially, VIF reflects how much the variance of a coefficient estimate has been overstated due to multicollinearity. It is often assumed that a VIF value less than 10 is typically considered indicative of no significant multicollinearity issue (Sulaiman et al., 2021).

3.4.5 Unit Root Test

In addition to the requirement of the absence of multicollinearity, the smoothness of variable data is a fundamental prerequisite for traditional econometric analysis. If the variable data are not stationary, it will produce serious consequences, such as pseudo-regression, making the research results unreliable (Xu & Xu, 2022). The Harris-Tzavalis (HT) test is commonly used to determine the presence of a unit root in panel data. This test uses normalised least squares estimators of the autoregressive coefficient and takes into account fixed effects and individual deterministic trends. It created asymptotic unit root tests for first-order autoregressive panel data models with serially uncorrelated errors (Harris & Tzavalis, 1999). The null hypothesis of this test is that the data is non-stationary, and if the test result rejects the null hypothesis, it means that there is no unit root in the variable data. In this study, the HT test is used to perform the stationarity test, which ensures the reliability of the panel data.

3.4.6 Cointegration Test

In unit root treatments, differencing the data of a variable to make it smooth is a standard method. However, this strategy affects the economic relevance of the original variables after the differencing process, which may obscure their intrinsic significance. This problem can be solved by running a cointegration test. The cointegration test evaluates whether non-stationary variables have a "long-term equilibrium relationship" due to underlying economic dynamics, allowing for meaningful regression analysis even when the variables are not stable separately (Masih & Masih, 1997). Furthermore, Pedroni (1999) extended the residual-based panel cointegration tests to include many independent variables in the regression equation, resulting in a strong framework for investigating these interactions. Cointegration theory is particularly useful for investigating the "long-term equilibrium relationship" between numerous variables (Liao et al., 2019). The null hypothesis of the Pedroni test states that there is no panel cointegration; rejecting this hypothesis and passing the cointegration test allows the data to advance to the next step of regression analysis, ensuring that long-term relationships are properly examined.

3.4.7 Hausman Test

Once the model has passed the cointegration test, it is ready for empirical statistical analysis. However, choosing the right econometric model is critical for producing reliable estimates. In panel data analysis, both fixed effects and random effects models are commonly used, though their data characteristics differ significantly (Clark & Linzer, 2015). The former model assumes that each individual has its own intercept, with the slope remaining constant across individuals. This applies when the differences between individuals are large and these differences are fixed. In contrast, the latter assumes that both intercepts and slopes can vary across individuals, with these differences being random. The Hausman test, developed by Hausman in 1978, is a method for detecting model misspecification by comparing an estimate that is efficient under the null hypothesis against one that is consistent under the alternative hypothesis. This test gives a formal statistical evaluation of whether unobserved individual effects are linked with the model's regressors, which is especially relevant when selecting whether to utilise fixed or random effects in panel data analysis (Le Gallo & Sénégas, 2023). In this study, the Hausman test is used to assess if individual effects are fixed or random, allowing us to select the better model for our investigation. The Hausman test helps to ensure that the chosen model appropriately reflects the underlying data structure, which improves the resilience and reliability of estimation results.

3.4.8 Stepwise Regression Method

In accordance with Hypotheses 2 and 3 of this paper, it’s necessary to apply the mediation effect model to investigate the mediating roles of industrial structure upgrading and green technology innovation. The stepwise regression method, developed by Baron and Kenny in 1986, has become a popular tool for determining the presence of a mediating effect (Baron & Kenny, 1986). Its validation steps are as follows: A variable functions as a mediator when it meets the following steps: (1) independent variable significantly affects dependent variable; (2) independent variable significantly affects mediating variable; and (3) once the mediating variable has been added, test whether the coefficients of the independent variable and mediating variable on the dependent variable are all significant, which is shown in Fig. 3.2.

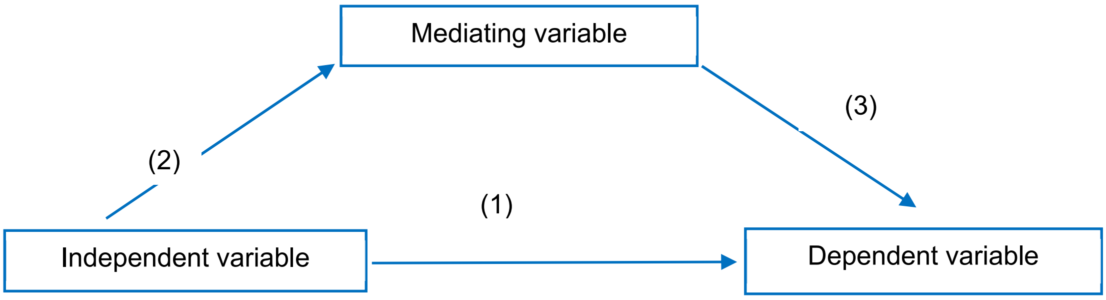

Figure 3.2: Diagram of statistical mediation
[Source: Baron & Kenny (1986)]

This study posits that both industrial structure upgrading and green technology innovation positively mediate the impact of green finance on green economic growth, corresponding to Hypotheses 2 and 3. Take Hypothesis 2 as an example; the process begins by examining the direct influence of green finance (independent variable) on green economic growth (dependent variable), as described in Hypothesis 1. Next, this study should explore the impact of green finance (independent variable) on industrial structure upgrading (mediating variable). If the findings indicate a significant impact, move on to the next phase; if not, no mediating effect is present. Finally, industrial structure upgrading (mediating variable) is incorporated into the model on the effect of green finance on green economic growth. If both green finance (independent variable) and industrial structure upgrading (mediating variable) significantly affect green economic growth (dependent variable), this suggests the presence of a mediating effect; otherwise, there is not.

3.4.9 Sobel Test

The Sobel test, a specialised method for evaluating mediation, is useful for quantifying the distinct impacts of mediation, such as direct, mediating, and total effects (Kumar et al., 2024). Researchers can establish whether the mediating impact is statistically significant by computing and analysing Sobel's z-value (Sobel, 1982). Furthermore, the modified Sobel test, which incorporates a fixed effect model, is used to assess the presence and extent of mediation. This enhanced approach takes into account individual impacts, providing a more comprehensive understanding of the model's mediating role. Therefore, this research adopts this technique to conduct a robust test of the mediating roles of industrial structure upgrading and green technology innovation in the link between green finance and green economic growth.

3.4.10 Endogeneity Test

Endogeneity, an important concern in this study, can result in biased coefficients and inaccurate findings. Scholars described it as the connection between explanatory variables and the error term in a regression, which is frequently caused by omitted variables, breaching a key assumption of ordinary least squares (OLS) regression analysis (Hill et al., 2021). Endogeneity can also result from bidirectional causation, in which the dependent variable influences explanatory factors, which then affect the dependent variable (Abdallah et al., 2015).

Endogeneity can be mitigated using a variety of strategies, including the generalised method of moments (GMM) and the instrumental variable (IV). Blundell and Bond developed the GMM model, which was specifically intended for dynamic panel data and uses lagged dependent variables as instruments to correct for endogeneity (Blundell and Bond, 1998). Endogeneity is addressed by the GMM technique, which uses a statistical procedure to deduct a variable's past value from its present value (Roodman, 2009). The IV technique attempts to compensate for endogeneity by incorporating variables that have no direct impact on the dependent variable but are associated with the explanatory variable and uncorrelated with the disturbance term. Instrumental variables are used to get a reliable estimate of the coefficient for the original explanatory variable (Bollen, 1996). The two-step least-squares estimator (2SLS) is a popular IV estimator that optimises IV combinations, allowing for consistent estimates of simultaneous equations with endogenous predictors (Pérez-Sánchez et al., 2024). 2SLS is well-known for its effectiveness and versatility in dealing with endogeneity-related challenges.

3.4.11 Robust Test

Robustness is defined as the stability of a result when subjected to various and independent means of determination. It gives epistemic support through triangulation, which states that if numerous, independent procedures reach the same conclusion, the result is more likely to be true (McPhail et al., 2018). They also claim that any approach that uses numerous robustness considerations to discern genuine findings from artefacts qualifies as a robustness analysis, regardless of the number or type of determination methods used. A robust test allows researchers to verify the stability of their estimates with several plausible model specifications, lowering the impact of model uncertainty on inference (Dejaegher & Vander Heyden, 2007). He established a number of robust testing strategies, including replacing one proxy variable with another, changing a variable's scale, and adding controls. These methods improve the reliability and validity of study findings by addressing potential sources of bias and variability and ensuring that results are consistent across different analytical methodologies.

3.5 Empirical Model

3.5.1 Model for the Relationship Between Green Finance and Green Economic Growth (Objective 1)

This study utilises dynamic panel data analysis with the System GMM model to elucidate the connection between green finance and green economic growth. Considering the presence of unobserved factors that are likely related to the observed variables in a fixed effect model, it might be underestimated while OLS estimators could be overestimated. Scholars often rely on the GMM method to tackle econometric challenges like heteroscedasticity, endogeneity, overidentification, and validity. System GMM, specifically, offers the benefit of tackling the endogeneity of all explanatory variables by utilising their lagged values as instrumental variables (Ullah et al., 2018). The first objective of the study will be to investigate the relationship between green finance and green economic growth, for which model (1) will be employed.

$$\mathrm{GEG_{it}} = \alpha_0 + \beta_0 \mathrm{GEG_{it-1}} + \beta_1 \mathrm{GF_{it}} + \beta_2 \mathrm{DV_{it}} + \sum \beta \mathrm{CV_{it}} + \varepsilon_{it} \qquad (1)$$

Where,

$\mathrm{GEG_{it}}$ = the dependent variable of green economic growth;

GEG_{it-1} = the lagged dependent variable of green economic growth;

$\mathrm{GF_{it}}$ = the independent variable of green finance;

$\mathrm{DV_{it}}$ = the dummy variable of Covid-19;

$\mathrm{CV_{it}}$ = the vector of control variables;

α_0 is the constant term;

β_0, β_1, β_2 , β are the estimated coefficients.

3.5.2 Model for the Mediating Role of Industrial Structure Upgrading (Objective 2)

This study uses the stepwise regression method to test the mediating role of industrial structure upgrading (ISU) on the relationship between green finance and green economic growth, thereby addressing the study's second objective. To better understand the mediating role of ISU, new models (2a) and (2b) are built in accordance with the strategy given by Baron and Kenny (1986). These models seek to comprehensively analyse how ISU influences the relationship between green finance and green economic growth, thereby offering a thorough understanding of the mediating effect of ISU in the link between green finance and green economic growth.

$$\mathrm{GEG_{it}} = \alpha_0 + \beta_0 \mathrm{GEG_{it-1}} + \beta_1 \mathrm{GF_{it}} + \beta_2 \mathrm{DV_{it}} + \sum \beta \mathrm{CV_{it}} + \varepsilon_{it} \qquad (1)$$

$$\mathrm{ISU_{it}} = \alpha_0 + \beta_0 \mathrm{ISU_{it-1}} + \beta_1 \mathrm{GF_{it}} + \beta_2 \mathrm{DV_{it}} + \sum \beta \mathrm{CV_{it}} + \varepsilon_{it} \qquad (2a)$$

$$\mathrm{GEG_{it}} = \alpha_0 + \beta_0 \mathrm{GEG_{it-1}} + \beta_1 \mathrm{GF_{it}} + \beta_2 \mathrm{ISU_{it}} + \beta_3 \mathrm{DV_{it}} + \sum \beta \mathrm{CV_{it}} + \varepsilon_{it} \qquad (2b)$$

Where,

$\mathrm{ISU_{it}}$ = the mediating variable of industrial structure upgrading;

$\mathrm{ISU_{it-1}}$ = the lagged mediating variable of industrial structure upgrading.

3.5.3 Model for the Mediating Role of Green Technology Innovation (Objective 3)

This study also uses the stepwise regression method to test the mediating role of green technology innovation (GTI) on the relationship between green finance and green economic growth, thus accomplishing the third objective. To study GTI's mediating role, two further models (3a) and (3b) are developed. These models are intended to systematically analyse how GTI influences the relationship between green finance and green economic growth, providing more insight into the mechanisms by which green finance promotes green economic growth.

$$\mathrm{GEG_{it}} = \alpha_0 + \beta_0 \mathrm{GEG_{it-1}} + \beta_1 \mathrm{GF_{it}} + \beta_2 \mathrm{DV_{it}} + \sum \beta \mathrm{CV_{it}} + \varepsilon_{\mathrm{it}} \quad (1)$$

$$\mathrm{GTI_{it}} = \alpha_0 + \beta_0 \mathrm{GTI_{it-1}} + \beta_1 \mathrm{GF_{it}} + \beta_2 \mathrm{DV_{it}} + \sum \beta \mathrm{CV_{it}} + \varepsilon_{\mathrm{it}} \quad (3a)$$

$$\mathrm{GEG_{it}} = \alpha_0 + \beta_0 \mathrm{GEG_{it-1}} + \beta_1 \mathrm{GF_{it}} + \beta_2 \mathrm{GTI_{it}} + \beta_3 \mathrm{DV_{it}} + \sum \beta \mathrm{CV_{it}} + \varepsilon_{\mathrm{it}} \quad (3b)$$

Where,

$\mathrm{GTI_{it}}$ = the mediating variable of green technology innovation;

$\mathrm{GTI_{it-1}}$ = the lagged mediating variable of green technology innovation.

3.6 Measurement of Variables

3.6.1 Dependent Variable

Green economic growth is based on the principle of sustainable development, with the goal of coordinating economic, social, and environmental development with the realisation of ecological, low-carbon, and circular economic development as the main content (Zvarych et al., 2023). Measuring the extent of green economic growth is crucial for a country or region to accurately evaluate the overall condition of economic and ecological development. Therefore, this study aims to create a comprehensive green economic growth index that accurately reflects the status of countries, filling the existing gap in a globally recognised index in the area of green finance and economic growth.

Firstly, as a development model coordinating economy, society, ecology, and environment (Hao et al., 2021), the green economic growth index is divided into 4 dimensions: economic development, social progress, ecological resources, and environment in this study. This dimensionality is able to compensate for some of the previous shortcomings (Platform, 2013; Rastogi et al., 2023). For example, they all neglect the important part of ecological resources, which is the foundation of sustainable human development on Earth.

Secondly, it is imperative to carefully choose appropriate indicators to assess each aspect. In this regard, the OECD has published the framework for green growth, which includes 156 segmentation indicators (OECD, 2017). The main limitation of this index is the accessibility and dependability of the data (Engelmann et al., 2019). In addition, (Merino-Saum et al., 2018) identified 14 regularly used indicators for analysing green economic growth. Hence, this study develops the green economic growth index using 11 indicators derived from past studies (Merino-Saum et al., 2018; OECD, 2017; Shao et al., 2022; J. Zhao et al., 2022). Moreover, Table 3.2 introduces a novel measure of female workforce participation.

Table 3.2: Indicator of green economic growth

Dimensions	Basic indicator	Attribute
Economic development	GDP per capita	+
	Proportion of total imports and exports to GDP	+
Social progress	Proportion of education expenditure to GDP	+
	Tertiary education enrolment rate	+
	Percentage of the female labour force	+
	Life expectancy	+
Ecological resources	Forest coverage rate	+
	GDP per unit of energy use	+
	Renewable energy consumption constructure	+
	Electric power consumption per capita	-
Environment	Greenhouse gas emissions per capita	-

Table 3.2 shows that economic development primarily signifies the current state and quality of the economic progress in a country or region. This study selects the indicators of GDP per capita and the ratio of total imports and exports to GDP. Furthermore, social progress refers to a society's capacity to provide fundamental needs, create opportunities for individuals and groups to enhance and maintain their current standard of living, and establish the conditions required for each person to achieve their maximum potential

(Boulton, 2022). It primarily encompasses metrics such as the ratio of education expenditure to GDP, the rate of tertiary education enrolment, the percentage of the female labour force, and life expectancy. Ecological resources primarily encompass metrics such as forest coverage rate, GDP per unit of energy use, renewable energy consumption infrastructure, and per capita electric power consumption. The environment is mainly measured by greenhouse gas emissions per capita.

3.6.2 Independent Variable

Green finance refers to the financing of projects aimed at the establishment of a circular economy, including promoting clean energy and reducing greenhouse gas emissions, and financial operations for other environmental objectives (Banga, 2019). Following the study of Umar and Safi (2023), this study adopts the expenditure allocated to public research and development for renewable energy.

3.6.3 Mediating Variable

3.6.3.1 Industrial Structure Upgrading

Industrial structure upgrading involves transforming an entire industry from a lower-level structure to a higher-level structure (Song et al., 2021). There are three primary approaches for assessing the upgrading of industrial structures. Firstly, studies used the angle cosine to reflect the variations of industrial structure by calculating the spatial vector (Su & Fan, 2022b). Secondly, studies utilised the weighted industry ratio index to illustrate the dynamic process of continuous improvement in the overall condition of industrial structure (Song et al., 2021). The specific expression is: ISU=$\sum_{n=1}^{3} \mathrm{y}_n * n$, n=1,2,3. Where y_n represents the proportion of the total output value of the n industry in GDP, ISU indicates industrial structure upgrading, ranging from 1 to 3. Thirdly, use the ratio of different industries or the ratio of industry to GDP to measure the advancement of industrial structure. For example, the output value of the tertiary industry to the secondary industry (Jiang et al., 2020) and the tertiary as a percentage of GDP (Q. Wang & L. Wang, 2021).This study employs the approach developed by Q. Wang and L. Wang (2021) to assess the upgrading of industrial structures. It specifically focuses on the ratio of the tertiary sector in GDP.

3.6.3.2 Green Technology Innovation

Green technology innovation refers to the implementation of green energy, equipment upgrades, and process improvements in order to reduce energy consumption, minimise environmental pollution, and enhance production efficiency in an industrial setting (Barbieri et al., 2020; Xie & Teo, 2022). Studies have conducted corresponding research on the measurement methods of green technology innovation, mainly including input and output indicators. The indicator relies on R&D investment as an input measure of innovation, which is a commonly used measurement. (Lee & Min, 2015; Tumelero et al., 2019). However, it does not guarantee the desired study outcomes nor provide insights into the results. Technological innovation output is a more accurate indicator of a company's innovation level since it takes into account the high failure rate and unpredictability associated with R&D operations, as opposed to R&D spending.

Furthermore, the indicator relies on the outcomes of environmentally friendly patents. Since patent applicant information can help identify innovation classification, patents are easily and accurately measured (Gorodnichenko & Schnitzer, 2013). The number of patents cannot be directly equated with the level of innovation, as it may take considerable time for patents to be applied in actual production. However, it can still serve as a useful indicator of technological innovation capacity to some extent (H. Wang et al., 2021). Studies have utilised the quantity of approved green patents from the OECD database as a metric for assessing the level of innovation in green technology (Shao et al., 2021; Xie et al., 2022). Therefore, the evaluation of green technology innovation in this study is based on the number of green technological patents.

3.6.4 Dummy Variable

The COVID-19 pandemic began on December 29, 2019, and was officially declared a global epidemic by the World Health Organisation (WHO) in 2020 (Ciotti et al., 2020). Consequently, the dummy variable is assigned a value of "0" for the years 2019 and earlier and a value of "1" for the years 2020, 2021, and 2022.

3.6.5 Control Variables

The study incorporates the control variables to consider their potential impact on the relationship between green finance and green economic growth, thereby ensuring a more thorough and precise analysis. The selection of control variables for this study is as follows:

(1) Financial development (FD): Improved financial development can result in greater availability of financial resources for environmental activities at reduced financing expenses (Tamazian & Bhaskara Rao, 2010). Furthermore, financial agglomeration has a significant impact on promoting urban green growth by facilitating both direct and geographical spillover effects (Tian et al., 2021). The measurement of financial development in this study is based on the ratio of liquid liabilities to GDP (Tamazian & Bhaskara Rao, 2010).

(2) Education: Education has been found to have a strong positive long- and short-term impact on green economic growth (X. Li et al., 2022). This study measures education by using the ratio of education expenditure to fiscal expenditure (Imana, 2017).

(3) Urbanisation: Urbanisation is a crucial factor in social and economic growth due to economies of scale in urban workforce aggregation, such as technology and energy usage. However, high urban population density can also lead to negative consequences, such as environmental damage and traffic congestion (Belloumi & Alshehry, 2016).

3.6.6 Summary of Variables

The measurement of variables in this study are summarised in Table 3.3.

Table 3.3: Summary of variables and data sources

Variables	Definition	Sources	References
GEG	The GEG index	World bank	Hao et al., 2021; Merino-Saum et al., 2018; OECD, 2017; J. Zhao et al., 2022.
Green finance	The natural logarithm of the budget spent on renewable energy public R&D.	OECD database	Umar & Safi, 2023.
Industrial structure upgrading	Ratio of tertiary sector in GDP.	World bank	Q. Wang & L. Wang, 2021.
Green technology innovation	The natural logarithm of the number of green patents.	OECD database	X. Shao et al., 2021; Xie et al., 2022.
Covid-19	"0" in 2019 and before, and "1" after 2019		Ciotti et al., 2020
FD	The natural logarithm of 100 * (the ratio of liquid liabilities to GDP)	World bank	Rashid & Intartaglia, 2017; Tamilselvan et al., 2022.
Education	Ratio of education expenditure to fiscal expenditure	World bank	Imana, 2017.
Urbanisation	Percentage of urban population	World bank	Belloumi & Alshehry, 2016

3.7 Summary

Chapter 3 outlines the research methodology. It begins by detailing the collection of samples and data for this study, which includes information from 28 developed countries from 1995 to 2022. Data on green economic growth, industrial structure upgrading, and control variables were sourced from the World Bank, while data on green finance and green technology innovation were obtained from the OECD database. The chapter then describes the data analysis techniques employed, which provide technical support for subsequent empirical findings. These techniques include the entropy-weighted TOPSIS method, descriptive statistical analysis, correlation analysis, multicollinearity test, stationarity test, cointegration test, Hausman test, stepwise regression method, Sobel test, endogeneity test, and robustness test. Furthermore, this chapter develops the models used to test both the direct effect and mediating effects, providing a detailed explanation of the study's independent, dependent, mediating, and control variables. This comprehensive approach ensures a robust analysis of the relationship between green finance, green economic growth, and the mediating role of industrial structure upgrading and green technology innovation.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter conducts empirical testing of the hypotheses and analyses the ensuing findings of the study. In Section 4.2, the index of green economic growth is calculated using the entropy-weighted TOPSIS approach before conducting the empirical evaluation. Afterward, relevant variables subjected to descriptive statistical analyses were discussed. Sections 4.4 and 4.5 provide the results of correlation analyses and multicollinearity tests, respectively. Subsequently, Sections 4.6 and 4.7 discussed stationarity and cointegration tests. Moreover, this study utilises various econometric models in Section 4.8, such as pooled OLS, two-way fixed effect model (TW-FE), random effect model, fixed effect model, two-step least-square estimator (2SLS), and the GMM. The purpose was to examine Hypothesis 1, which suggests that green finance has a positive impact on green economic growth. In Section 4.9, this study used the stepwise regression method to investigate Hypothesis 2 in accordance with the reliability of the findings by using the modified Sobel test. In Section 4.10, this study discusses the findings of the mediating influence of green technology innovation. Lastly, Section 4.11 provides a concise overview of Chapter 4.

4.2 Measurement of the Green Economic Growth Index by Entropy-weighted TOPSIS Method

Before analysing the data, the green economic growth index should be evaluated to get a detailed understanding of the dependent variable. As mentioned in the previous section 3.6.1, this study develops the green economic growth index using 11 indicators derived from prior studies (Merino-Saum et al., 2018; OECD, 2017; J. Zhao et al., 2022). The index is presented in Table 3.1. The entropy-weighted TOPSIS method is adopted to evaluate the green economic growth index. This method is chosen because it allows for a more objective determination of both the weight and the decision result (X. Yu et al., 2020). The process of this method has been thoroughly explained in section 3.4.1.

Once the initial matrix $(X_{t,j})_{n*m}$ has been constructed, it represents the value of the j indicator in year t. After the data has been standardised, it becomes apparent that in Table 3.1, the column labelled 'Attribute' contains two negative indicators: electric power consumption per capita and greenhouse gas emissions per capita. These indicators are not beneficial for green economic growth and require reverse processing. The remaining nine positive signs require further processing in a forward direction. The entropy weight approach is employed to determine the values of information entropy value E_j, information utility value d_j, shown in Table 4.1.

Table 4.1: Results of entropy value and Utility value

Indicators	Information entropy value E_j	Information utility value d_j
GDP per capita	0.9764	0.0236
Proportion of total imports and exports to GDP	0.9696	0.0304
Proportion of education expenditure to GDP	0.9872	0.0128
Tertiary education enrolment rate	0.9891	0.0109
Percentage of female labour force	0.9933	0.0067
Life expectancy	0.9923	0.0077
Forest coverage rate	0.9756	0.0244
GDP per unit of energy use	0.9772	0.0228
Renewable energy consumption constructure	0.9477	0.0523
Electric power consumption per capita	0.997	0.003
Greenhouse gas emissions per capita	0.994	0.006

Subsequently, the weight of indicator j was calculated based on the value of the information entropy value and utility, as shown in Table 4.2. Each indicator was assigned a weight, with the weight W_j increasing as the value of d_j increased. The first five indicators calculated by the entropy method are renewable energy consumption, proportion of total imports and exports to GDP, forest coverage rate, GDP per capita, and GDP per unit of energy use.

Table 4.2: Results of weighting of indicators

Indicators	Weight W_j
GDP per capita	11.78%
Proportion of total imports and exports to GDP	15.14%
Proportion of education expenditure to GDP	6.36%
Tertiary education enrolment rate	5.43%
Percentage of female labour force	3.32%
Life expectancy	3.87%
Forest coverage rate	12.17%
GDP per unit of energy use	11.36%
Renewable energy consumption constructure	26.08%
Electric power consumption per capita	1.47%
Greenhouse gas emissions per capita	3.02%

After calculating the weights of all indicators, the TOPSIS method was employed to find out the positive and negative ideal solution values (A^+ and A^-

) of the indicators. The positive ideal solution A^+ is the maximum value of A^-; the negative ideal solution A_t^- is the minimum of $A_{t,j}$. Table 4.3 displays the outcomes of both the positive and negative perfect solutions.

Table 4.3: Positive and negative ideal solutions

Indicator	Positive ideal solution(A^+)	Negative ideal solution (A^-)
GDP per capita	0.119	0.001
Proportion of total import and export to GDP	0.153	0.002
Proportion of education expenditure to GDP	0.064	0.001
Tertiary education enrolment rate	0.055	0.001
Percentage of female labour force	0.034	0
Life expectancy	0.039	0
Forest coverage rate	0.123	0.001
GDP per unit of energy use	0.115	0.001
Renewable energy consumption constructure	0.263	0.003
Electric power consumption per capita	0.015	0
Greenhouse gas emissions per capita	0.03	0

Subsequently, the distance from each ideal solution to the positive ideal solution distance (D_i^+) and the negative ideal solution distance (D_i^-), was calculated along with the relative proximity of the green economic growth index (C_t). The relative proximity of the green economic growth index (C_t) can be determined by calculating the ratio of the negative ideal solution to the sum of the positive and negative ideal solutions. The parameter C_t represents the degree of closeness between the evaluation object and the optimal solution. A higher value implies closer proximity to the optimal solution. The findings of the green economic growth index are displayed in Table 4.4.

Table 4.4: Results of the Green Economic Growth Index (C_t)

Country	1995	2001	2007	2013	2019	2022
Australia	0.159	0.179	0.195	0.211	0.218	0.231
Austria	0.272	0.287	0.299	0.322	0.323	0.334
Belgium	0.170	0.188	0.257	0.273	0.279	0.293
Canada	0.257	0.252	0.260	0.265	0.270	0.282
Czech Republic	0.191	0.190	0.200	0.213	0.230	0.281
Denmark	0.201	0.230	0.253	0.277	0.308	0.326
Finland	0.339	0.351	0.361	0.380	0.397	0.411
France	0.186	0.218	0.228	0.242	0.249	0.259
Germany	0.172	0.209	0.227	0.240	0.256	0.260
Greece	0.147	0.184	0.208	0.231	0.249	0.257
Iceland	0.285	0.325	0.351	0.378	0.403	0.413
Ireland	0.148	0.227	0.253	0.262	0.381	0.397
Israel	0.176	0.180	0.185	0.199	0.208	0.578
Italy	0.161	0.207	0.217	0.234	0.241	0.254
Japan	0.266	0.269	0.275	0.281	0.289	0.288
Korea	0.270	0.274	0.280	0.284	0.294	0.298
Luxembourg	0.285	0.354	0.377	0.378	0.438	0.470
Netherlands	0.164	0.181	0.196	0.211	0.269	0.283
New Zealand	0.255	0.265	0.281	0.282	0.279	0.288
Norway	0.371	0.380	0.387	0.388	0.400	0.391
Portugal	0.237	0.236	0.247	0.271	0.270	0.292
Slovak Republic	0.203	0.207	0.260	0.268	0.281	0.282
Slovenia	0.268	0.291	0.298	0.306	0.343	0.355
Spain	0.168	0.211	0.224	0.250	0.257	0.273
Sweden	0.345	0.364	0.378	0.399	0.418	0.454
Switzerland	0.265	0.281	0.302	0.316	0.341	0.362
United Kingdom	0.171	0.180	0.197	0.211	0.228	0.246
United States	0.231	0.230	0.229	0.232	0.238	0.247

4.3 Descriptive Statistical Analysis

Descriptive statistics is the initial understanding of the data source before going for further analysis, as it provides a comprehensive overview of the raw data. Table 4.5 displays a total of 784 observations, encompassing 28 counties and spanning 28 years. The statistical analysis reveals that the green economic growth (GEG) value varies between 0.143 and 0.578, with an average of 0.268. The average value is in closer proximity to the minimum, suggesting that the majority of counties exhibit low levels of GEG. Nevertheless, the standard deviation of 0.268 indicates that the dispersion of GEG across all counties is minimal over the investigated time. The distribution of industrial structure upgrading (ISU), Covid-19, financial development (FD), education, and urbanisation is somewhat evenly spread, although green finance (GF) and green technology innovation (CTI) exhibit a higher degree of variation.

Table 4.5: Descriptive statistics of variables

Variable	Observations	Mean	Std.Dev.	Min	Max
GEG	784	0.268	0.067	0.143	0.578
GF	784	6.544	2.236	1.138	11.099
ISU	784	0.732	0.058	0.498	0.894
CTI	784	5.022	2.064	0	9.264
Covid-19	784	0.107	0.309	0	1
FD	784	4.517	0.567	2.130	6.832
Education	784	0.120	0.026	0.057	0.179
Urbanisation	784	0.779	0.116	0.506	0.982

4.4 Correlation Analysis

In order to have a preliminary understanding of the relationship between the variables, the correlation coefficients and significance levels for each variable are conducted by Pearson's correlation test, as presented in Table 4.6. GEG shows a significant correlation with GF, GTI, Covid-19, financial development, education, and urbanisation. Using the correlation matrix as a basis, all other correlation coefficients are below 0.7 with the exception of the core independent variable of green finance and the mediator variable of green technology innovation, which has a correlation coefficient of 0.88. This implies that green finance and green technology innovation exhibit a common trend and are linearly correlated, which could lead to multicollinearity issues and result in biased outcomes. The challenge arises from the difficulty in distinguishing the individual contributions of these independent variables to the dependent variable, as they may compete to explain most of the similar variance (Kim, 2019). However, a high correlation coefficient is not sufficient to establish causality; it merely indicates the potential presence of multicollinearity (Haitovsky, 1969; Kalnins, 2018). Consequently, a multicollinearity test will be conducted in the subsequent stage to tackle the issue of multicollinearity.

Table 4.6: Correlation matrix

Variables	GEG	GF	ISU	GTI	Covid-19	FD	Education	Urbanisation
GEG	1.000							
GF	-0.223***	1.000						
ISU	-0.035	-0.029	1.000					
GTI	-0.158***	0.877***	0.090**	1.000				
Covid-19	0.236***	0.067*	0.097***	0.015	1.000			
FD	0.180***	-0.023	0.478***	0.120***	0.194***	1.000		
Education	0.336***	-0.125***	-0.081**	0.036	0.016	-0.171***	1.000	
Urbanisation	0.127***	0.175***	0.349***	0.266***	0.071***	0.233***	0.270***	1.000

Note= * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

4.5 Multicollinearity Test

Given the high correlation between green finance and green technology innovation, which may introduce multicollinearity issues in the model, it is necessary to conduct further tests to determine the presence of multicollinearity. The variance inflation factor (VIF), which measures how multicollinearity inflates the variance of an estimator, is commonly employed to examine multicollinearity issues (Lavery et al., 2019). A VIF value exceeding 10 indicates a severe multicollinearity problem (Senaviratna & Cooray, 2019; Sulaiman et al., 2021), while a VIF below 10 suggests that multicollinearity is not a significant concern and can typically be disregarded (Garib et al., 1997; Yilmaz et al., 2007; York, 2012). The results of the multicollinearity test in this study show that all variables have a VIF value below 6, with a mean VIF of 2.67. This suggests that the multicollinearity can be ignored in this study, as presented in Table 4.7.

Table 4.7: Results of multicollinearity test

Variables	GTI	ISU	GF	Covid-19	FD	Education	Urbanisation
VIF	5.84	1.45	5.93	1.09	1.55	1.41	1.39
Mean VIF				2.67			

4.6 Unit Root Test

The smoothness of variable data is one of the basic requirements of traditional econometric analysis before conducting empirical tests. A unit root test is a statistical test that determines whether a time series variable is non-stationary and has a unit root. Essentially, it assists in determining if a time series is marked by a random trend. A time series that exhibits a unit root is considered non-stationary due to its statistical characteristics, such as mean and variance, which vary over time. Consequently, this study performs a unit root test using the HT test. According to the data in Table 4.8, the variables of green finance, industrial structure upgrading (ISU), green technology innovation (GTI), financial development, and education have passed the unit root test. However, the variables of green economic growth (GEG) and urbanisation have unit roots, indicating that the data is non-stationary. Nevertheless, the non-stationary variables become stationary after using the first-order difference treatment. In order to ascertain whether the variables possess a long-term equilibrium relationship, it is necessary to conduct a cointegration test.

Table 4.8: Unit root test for variables

Variable	Test method		Stationarity	
	HT test	P-value	No treatment	After difference
GEG	6.277	1.000	No	Yes
GF	-2.968	0.002	Yes	
ISU	-2.001	0.023	Yes	
GTI	-3.009	0.001	Yes	
FD	-4.877	0.001	Yes	
Education	-1.868	0.031	Yes	
Urbanisation	3.7358	1.0000	No	Yes

4.7 Cointegration Test

Despite being processed using differential treatment, the variables passed the unit root test. However, it may cause another problem, namely that the economic meaning of the variables has changed significantly. If special economic pressures result in a "long-term equilibrium relationship" among non-stationary variables, the regression analysis could be performed.

Variables exhibit long-term equilibrium relationships or indicate a shared trend, which is known as cointegration (Masih & Masih, 1997). The Pedroni test was employed to ascertain whether the variables in distinct models exhibit a sustained equilibrium connection, as presented in Table 4.9. The result of the cointegration test shows a significance level of 0.05, which confirms that all variables in model 1 exhibit a long-term equilibrium relationship and are suitable for panel regression analysis. Models (2a) and (2b) examine whether industrial structure upgrading acts as a mediator and determine that the variables in models (2a) and (2b) pass the stationarity test at the 0.1 significance level. This indicates that they have a long-term equilibrium connection and can be analysed using panel regression. In addition, models (3a) and (3b) examine whether green technology innovation acts as a mediator and show that the variables in models (3a) and (3b) pass the stationarity test at the 0.1 significance level. This indicates that these variables have a long-term equilibrium relationship and can be analysed using panel regression.

Table 4.9: Cointegration test for models

Model	Pedroni test for cointegration		
	Modified Dickey-Fuller	Phillips-Perron	Augmented Dickey-Fuller
Model. (1)	2.270**	-6.140***	-6.549***
Model. (2a)	3.782***	-1.580*	-2.164**
Model. (2b)	3.511***	-5.797***	-5.930***
Model. (3a)	-1.435*	-6.582***	-6.715***
Model. (3b)	2.416***	-7.343***	-7.105***

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

4.8 Objective 1: The Relationship between Green Finance and Green Economic Growth

4.8.1 Result of Objective 1

In order to examine the relationship between the independent variable of green finance and the dependent variable of green economic growth (objective 1), this study used various statistical models, including pooled OLS, two-way fixed effect (TW-FE), random effect (RE), fixed effect (FE), 2SLS, and the System GMM models using STATA16.0. The findings are displayed in Table 4.10.

Table 4.10: Relationship between green finance and green economic growth

Variables	OLS	TW-FE	RE	FE	2SLS	System GMM
GEG_{it-1}						0.763***
						(0.160)
GF	-0.006***	-0.002	0.005***	0.006***	0.006***	0.007***
	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)
Covid-19	0.045***	0.101***	0.030***	0.028***	0.028***	-0.002
	(0.007)	(0.007)	(0.003)	(0.003)	(0.003)	(0.006)
FD	0.023***	-0.007*	0.025***	0.023***	0.022***	0.040*
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.024)
Education	0.885***	0.535**	0.690***	0.688***	0.694***	0.555*
	(0.090)	(0.069)	(0.079)	(0.080)	(0.083)	(0.305)
Urbanisation	0.006	-0.019	0.333***	0.405***	0.422***	-0.080
	(0.020)	(0.045)	(0.041)	(0.044)	(0.046)	(0.052)
cons	0.087***	0.221***	-0.227***	-0.279***		-0.162**
	(0.024)	(0.041)	(0.003)	(0.033)		(0.076)
N	784	784	784	784	756	756
F-statistic	49.23***					
AR(1)						P=0.013
AR(2)						P=0.484
Hansen test						P=0.490

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

The pooled OLS model is initially employed to analyse the data. The value of F-statistic is 49.23 (p<0.01), indicating that the constraints are unacceptable and each variable should be further discriminated for significance. The results of this model reveal that green finance has a negative impact on green economic growth, contradicting Hypothesis 1. After that, this study utilises the two-way fixed effect model, taking into account a sample period of 28 years, from 1995 to 2022. The findings indicate that green finance also has a negative impact on green economic growth, with no statistically significant effect. Subsequently, this study adopts both random and fixed effect models, and the comparative outcomes of the Hausmann test indicate that the fixed effect model is more appropriate than the random effect model. Moreover, the results of the fixed effect model suggest that green finance has a positive impact on promoting green economic growth in developed countries.

It also shows that governments are effectively guiding the implementation of eco-friendly economic growth through green financial policies. For stakeholders, green financial investment in eco-projects offers a win-win situation in terms of both economic and social-environmental benefits, thus realising sustainable economic development. This investment channel offers innovative and enduring value, with strong backing from both the government and financial institutions for green projects. Nevertheless, both Covid-19 and control variables clearly contribute to the enhancement of green economic growth.

To address the possible problems of endogeneity and autocorrelation, this study employs the 2SLS and the system GMM. During 2SLS analysis, the variable "green finance" was substituted with its first-order lag term, and the findings were closely aligned with the outcomes of the fixed effect model. The results of system GMM indicate that green finance has a statistically significant positive impact on green economic growth (beta=0.007), above the significance level test of 0.01. It means that one unit of green finance can lead to 0.007 units of green economic growth. Furthermore, the P-value for the first-order autoregressive term (AR (1)) is 0.013, and for the second-order autoregressive term (AR (2)), it is 0.484, indicating that both terms pass the autocorrelation test. The Hansen test yields a P-value of 0.490, passing the over-identification test. Therefore, the findings of the System GMM indicate that green finance significantly and positively contributes to green economic growth. Therefore, the evidence supports Hypothesis 1, which states that green finance has a positive impact on green economic growth.

4.8.2 Robust Test of Objective 1

This study employs two methodologies to conduct a robust examination of the direct impact, which involve replacing the dependent variable and introducing control variables. Firstly, this study replaces the essential indicator of green economic growth with its basic component, per capita greenhouse gas emissions (GHG), which was logarithmically transformed. The results, displayed in Table 4.11, demonstrate that when GHG was considered as the dependent variable, the implementation of green finance leads to a substantial reduction in GHG, suggesting a detrimental impact on the environment. The replacement variable provides empirical evidence of the adaptability and robustness of the findings. Furthermore, the study includes two additional control variables. One of the variables considered is population density, which was included based on prior research (Chin et al., 2022). The second factor was government intervention, which was quantified by the ratio of fiscal expenditure to GDP. Fiscal expenditure is an essential element of the overall GDP (López et al., 2011) and was recognised as a significant factor influencing economic growth (Facchini & Seghezza, 2018). Table 4.11 confirms that the regression results remain largely constant even when these control factors are taken into account, highlighting the study's findings as being resilient and robust.

Table 4.11: Results of robust test for objective 1

Variables	Replacing variable	Adding variables
	GHG	GEG
GHG_{it-1}	1.111***	
	(0.045)	
GEG_{it-1}		0.841***
		(0.085)
Green finance	-0.018**	0.008***
	(0.009)	(0.002)
Covid-19	-0.047***	-0.006
	(0.005)	(0.006)
FD	0.033	0.033**
	(0.052)	(0.014)
Education	-0.392	0.501***
	(0.327)	(0.192)
Urbanisation	-0.053	-0.076**
	(0.111)	(0.036)
Population density		-0.001**
		(0.001)
Government intervention		0.074**
		(0.037)
_cons	-0.214	-0.186
	(0.272)	(0.064)
AR(1)	P=0.001	P=0.014
AR(2)	p=0.996	p=0.528
Hansen test	P=0.779	P=0.372

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

4.8.3 Discussion of Objective 1

The findings of this study provide evidence that green finance has a positive impact on green economic growth in developed countries. Theoretically, the Green Finance Theory aims to promote the development of green projects and a green economy by providing green financial policies, thereby benefiting green economic growth in wealthy nations.

This outcome differs markedly from previous studies. For example, Gan and Voda (2023) argue that green finance increases carbon emission intensity in China through structural transformation, which is detrimental to sustainable growth. This is because green finance promotes the transformation of industry, while this shift in industry structure leads to higher carbon intensity by increasing energy and resource consumption. Similarly, scholars find that there is a U-shaped relationship between green finance and green economic growth in Chinese provinces J. Zhang et al. (2022). Their study suggests that green finance initially dampens growth but later facilitates it as scale and efficiency improve.

However, the findings in this study are also supported in developed and developing nations by other prior studies. For instance, it has been demonstrated that green finance lowers carbon in the G7 countries between 1995 and 2019 (Sharif et al., 2022) and in BRICS countries (X. Wang et al., 2021). The positive influence of green finance on economic growth is attributed to the supply of focused financial assistance for green activities, which not only stimulate economic progress but also generate environmental advantages. Moreover, green finance enhances economic growth by mitigating the risks linked to green initiatives. Financial institutions utilise extensive risk management measures to mitigate investment risks associated with green initiatives, hence guaranteeing their long-term viability (Chen & Chen, 2021). Throughout history, the process of industrialisation in wealthy countries has resulted in economic growth but also caused harm to the environment. This has led to increased awareness and efforts to tackle environmental problems. In 2007, the European Investment Bank introduced the world's inaugural green bond to aid green initiatives and promote renewable energy development as a response to the environmental problem (Nguyen et al., 2021). Moreover, it has been found that adopting green finance policies has contributed to improving environmental sustainability in G20 nations (Ma et al., 2023).

The study also takes into account the impact of dummy and control variables. The COVID-19 dummy variable exhibits a negative effect on green economic growth; however, this effect is not statistically significant. This phenomenon may be attributed to the pandemic's restriction on population movement and consumption, specifically in terms of offline contact consumption. Consequently, this has led to a decrease in company orders and production demand, resulting in a dampening effect on economic growth. It is worth noting that despite the good environmental benefits of the epidemic, these factors have nonetheless hindered economic growth. However, this study reveals that financial development plays a crucial role in promoting green economic growth, as financial agglomeration has the potential to boost urban green economic growth by facilitating both direct and geographical spillover effects (Tian et al., 2021).

In addition, another finding in this study that education fosters green economic growth is consistent with earlier research employing Chinese samples, which found that education suggests a significant and beneficial influence of education on green economic growth (X. Li et al., 2022). Nevertheless, it has been found that green economic growth is negatively impacted by urbanisation, although this effect is not significant. The reason may be that urbanisation is a double-edged sword, with economies of scale such as technology and energy use as well as negative effects such as environmental pollution (Belloumi & Alshehry, 2016). Therefore, urbanisation, in general, seems to have a negative impact on green economic growth in this study.

The findings of this study confirm that it is possible to encourage green economic growth in developed countries by implementing green financial policies. Nevertheless, there are pragmatic obstacles to executing such tactics in developing countries. These countries are confronted with a dilemma where they must balance the pursuit of economic expansion with the need for environmental conservation (Du & Yi, 2022). Additionally, their governments frequently lack adequate financial resources specifically allocated for climate change projects, in contrast to developed countries. In addition, insufficient environmental legislation and irregularities in management might additionally reduce the efficiency of green finance, impeding the attainment of green economic growth in developing countries.

4.9 Objective 2: Mediating Role of Industrial Structure Upgrading

4.9.1 Result of Objective 2

Objective 2 was to investigate the mediating role of industrial structure upgrading in the relationship between green finance and green economic growth. According to the stepwise regression method, this paper requires three steps to verify its mediating role in models (1), (2a), and (2b). First, the study ought to investigate whether green finance (independent variable) facilitates green economic growth (dependent variable). Second, the impact of green finance (independent variable) on industrial structure upgrading (mediating variable) should be examined in this study. If the results indicate a significant impact, the next step can be pursued; otherwise, no mediating effect exists. Lastly, the model on the relationship between green finance and green economic growth is expanded to include the mediating variable of upgrading industrial structure. A mediating role is confirmed if both green finance and industrial structure upgrading significantly affect green economic growth; if not, no mediating effect is observed.

The results from model (1) in Table 4.12 indicate a positive relationship between the independent variable of green finance and the dependent variable of green economic growth. It demonstrates that one unit of green finance can lead to 0.007 units of green economic growth. Furthermore, the P-values for the AR (1), AR (2), and Hansen tests all meet the necessary criteria. A relevant study has shown that green finance provides financial services that support the development of environmentally sustainable economic activities (Geng et al., 2023).

Following that, the second stage involves investigating whether the independent variable of green finance has a notable impact on the mediating variable of industrial structure upgrading, as observed in model (2a). The regression analysis shows that the coefficient of green finance on industrial structure upgrading is 0.008, which is statistically significant at the 0.05 level. This suggests that one unit of green finance can lead to 0.008 units of the upgrading of industrial structures. Furthermore, studies have shown that green finance plays a crucial role in facilitating the necessary improvement of the industrial structure by employing several strategies, such as green credit and green bonds (Nur Utomo et al., 2020). In addition, the P-values obtained from the Hansen test, AR (1), and AR (2) all satisfy the required conditions.

Moreover, model (2b) examines the impact of the independent variable of green finance and the mediating variable of industrial structure upgrading on the dependent variable of green economic growth. The regression analysis shows that the coefficient of green finance on green economic growth is 0.005, surpassing the significance level of 0.01. This suggests that for every one unit of green finance, there is an associated increase of 0.005 units in green economic growth. Simultaneously, the coefficient of industrial structure upgrading on green economic growth is 0.098, surpassing the significance level test of 0.05. This suggests that 0.098 units of green economic growth result from one unit of industrial structure upgrading. The findings align with prior research, which suggests that upgrading the industrial structure can enhance green growth through both direct effects and spatial spillover effects (Xu & Zhou, 2023). Furthermore, the P-values for AR (1), AR (2), and the Hansen test all meet the required criteria to test the mediating role of industry structure upgrading between green finance and green economy growth, as shown in Table 4.12.

Table 4.12: Results of mediating effect of industrial structure upgrading

Variable	Model (1)	Model (2a)	Model (2b)
	GEG	**ISU**	**GEG**
GEG_{it-1}	0.763***		0.970***
	(0.160)		(0.029)
ISU_{it-1}		0.889***	
			(0.025)
ISU			0.098**
			(0.042)
Green finance	0.007***	0.002***	0.005***
	(0.002)	(0.001)	(0.002)
Covid-19	-0.002	-0.006***	0.004**
	(0.006)	(0.001)	(0.002)
FD	0.040*	0.006***	-0.003
	(0.024)	(0.002)	(0.005)
Education	0.555*	0.025	0.221***
	(0.305)	(0.024)	(0.066)
Urbanisation	-0.080	0.004	-0.032***
	(0.052)	(0.008)	(0.022)
_cons	-0.162**	0.035***	-0.083***
	(0.076)	(0.009)	(0.024)
N	756	756	756
AR(1)	P=0.013	P=0.008	P=0.005
AR(2)	P=0.484	P=0.304	P=0.637
Hansen test	P=0.490	P=0.692	P=0.137

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

In conclusion, this study compiles all the findings from the analysis of the mediating effects test of industrial structure upgrading, as presented in Table 4.12. Based on the stepwise regression method, the initial step reveals that green finance has a statistically significant positive impact on green economic growth (beta=0.007, P<0.01) in Model (1). In model (2a), the second step reveals that green finance has a significant impact on industrial structure upgrading (beta=0.002, P<0.01). In model (2b), the third step reveals that green finance and industrial structure upgrading both have a substantial impact on green economic growth. The coefficients for these variables are 0.005 ($P<0.01$) and 0.098 ($P<0.05$), respectively. Therefore, the findings indicate that the upgrading of industrial structures plays a significant role in mediating the relationship between green finance and green economic growth. Therefore, this study concluded that Hypothesis 2, which states that the upgrading of industrial structure acts as a positive mediator in the relationship between green finance and green economic growth, is accepted.

4.9.2 Robust Test of Objective 2

This study adopts a modified Sobel test with a fixed effect model to determine the robustness of industrial structure upgrading as a mediating variable. According to the data in Table 4.13, green finance has a strong positive impact on green economic growth. The coefficient (beta) for this relationship is 0.006, and it is statistically significant at a level of $p<0.01$ in Column (1). The impact of green finance on the upgrading of industrial structures is likewise significant, as evidenced by a coefficient of 0.003 in Column (2), above the significance threshold test of 0.05. In addition, both the independent variable (green finance) and the mediating variable (industrial structure upgrading) had positive and significant impacts on the dependent variable (green economic growth) in Column (3), with coefficients of 0.006 ($p<0.1$) and 0.226 ($p<0.01$), respectively. The revised Sobel test findings demonstrate that the mediator of industrial structure upgrading successfully passes the Sobel test (z=1.832, p=0.067), with the indirect effect constituting 8.94% of the total effect. This indicates that 8.94% of the influence of green finance on green economic growth is conveyed through the mediating role of upgrading the industrial structure.

Table 4.13: Robust test for mediating effect of industrial structure upgrading

Variable	(1) GEG	(2) ISU	(3) GEG
ISU			0.226***
			(0.045)
Green finance	0.006***	0.003**	0.006***
	(0.002)	(0.003)	(0.002)
Covid-19	0.006***	-0.007***	0.030***
	(0.002)	(0.003)	(0.003)
FD	0.023***	0.038***	0.014
	(0.004)	(0.003)	(0.004)
Education	0.688***	0.051	0.678***
	(0.080)	(0.063)	(0.078)
Urbanisation	0.405***	0.403***	0.314***
	(0.044)	(0.035)	(0.047)
_cons	-0.279***	0.224***	-0.330***
	(0.033)	(0.026)	(0.034)
Sobel test		z=1.832*	
Indirect effect		z=1.832*	
Direct effect		z=3.653***	
Total effect		z=3.960***	
Proportion of indirect effect		8.94%	

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

To summarise, the results of the modified Sobel test using the fixed effect model indicate that industrial structure upgrading acts as a positive and significant mediator in the relationship between green finance and green economic growth. These findings emphasise the robustness of the study findings.

4.9.3 Discussion of Objective 2

The study's findings demonstrated that the upgrading of industrial structures played a positive and significant role in mediating the relationship between green finance and green economic growth in developed countries. Furthermore, it was noted that 8.94% of the influence of green finance on green economic growth was conveyed through the mediating role of upgrading industrial structures. The results are consistent with the Industrial Diffusion Theory. Green finance initiatives limit the development of polluting industries while encouraging the development of eco-friendly industries. As a result, this promotes the upgrading of industrial structures and reduces environmental pollution, ultimately leading to the promotion of green economic growth.

Specifically, the process of upgrading the industrial structure was also positively influenced by green finance policies, which involved the reallocation of financial resources from the primary and secondary sectors to the tertiary industry. Both the primary and secondary industries, especially the latter, substantially depend on resources and produce substantial levels of pollution and consumption in reality. On the other hand, the tertiary industry, which mostly includes software, IT, and service sectors, provides the greatest amount of value added, releases the fewest pollutants, and effortlessly fulfils environmental protection standards. Industrial structure upgrading leads to green economic growth by reducing the importance of primary and secondary sectors and increasing the significance of the tertiary industry, which has the highest value and causes the least pollution based on the Industrial Diffusion Theory.

Relevant research has revealed that industrial structure upgrading makes great contributions to green economic growth in both China (Zhu et al., 2019) and OECD nations (Chang et al., 2024; Lei et al., 2024). Although no study has focused on the mediating role of industrial structure upgrading in the link between green finance and green economic growth. The literature has provided some evidence for the mediating effect of industrial structure upgrading in other connections. For instance, industrial structure upgrading in China mediates the negative relationship between financial development and carbon emissions; that is, financial development improves industrial structure upgrading, which in turn reduces carbon emissions (Feng & Wu, 2022). However, there are numerous important differences between this research and the previous studies that need serious consideration. This study highlights the increased importance placed by green finance on environmental preservation, in contrast to this prior study that mainly focused on the impact of financial development. Furthermore, the all-encompassing nature of green economic growth, which includes not just environmental factors but also economic and social advancement, sets it apart from the narrower focus of this prior study.

Furthermore, it is recommended from the finding of the mediating role of industrial structure upgrading in this study that governments prioritise industrial structure upgrading in order to accelerate the transition towards a green economy by promoting its progress. Nevertheless, in actuality, industrial structure upgrading in OECD countries is significantly more advanced than in developing nations. In 2022, Germany had a ratio of tertiary to GDP of 72.18%, and the United Kingdom had a ratio of 82.55%. In this respect, China, a rapidly growing market, has successfully achieved a 52.8% level of industrial structure upgrading, despite seeing a 27% increase over the past two decades. The difference can be attributed to China's historical dependence on the secondary sector as the main catalyst of its national economy. This sector, characterised by high energy consumption and pollution, is a major contributor to environmental deterioration (Fang & Yu, 2021). Therefore, in OECD countries, the positive influence of green finance on green economic growth is enhanced by the upgrading of industrial structures. However, in developing countries, the effectiveness of this influence is significantly reduced due to persistent concrete impediments and challenges. This gives inspiration for differentiated industrial upgrading policies in developed and developing countries.

4.10 Objective 3: Mediating Role of Green Technology Innovation

4.10.1 Result of Objective 3

Objective 3 was to investigate the mediating role of green technology innovation in the relationship between green finance and green economic growth. Based on the method of stepwise regression, this paper also conducts three steps to verify its mediating role in models (1), (3a), and (3b). First, this research should explore the supporting role of green finance (independent variable) on green economic growth (dependent variable). Second, this study needs to explore the impact of green finance (independent variable) on industrial structure upgrading (mediating variable). If the outcomes confirm a significant impact, move on to the next step; if not, there isn't a mediating effect.

Finally, the mediating variable of green technology innovation is added to the model on the effect of green finance on green economic growth. If the results show that both green finance and green technology innovation have an obvious effect on green economic growth, then it indicates that there is a mediating role of green technology innovation; otherwise, there is not.

As presented in Table 4.14, the results from model (1) demonstrate that the independent variable of green finance has a positive effect on the dependent variable of green economic growth. This implies that 0.007 units of green economic growth can result from one unit of green finance. The positive correlation is ascribed to green finance, which offers financial services that facilitate the advancement of green economic growth (Geng et al., 2023). The P-values for the first-order autoregressive (AR) model, the second-order AR model, and the Hansen test all satisfy the necessary statistical criteria.

In the second step, model (3a) investigates the impact of green financing on green technology innovation. The regression analysis reveals that the coefficient of green finance on green technology innovation is 0.275, which surpasses the significance level of 0.05. This suggests that 0.275 units of green technology can be attributed to one unit of green finance. And it has also been found that green finance is employed to finance green technology projects, which helps in the shift towards renewable energy and sustainable development (Madaleno et al., 2022). Moreover, green finance plays a role in fostering green innovation by supporting advancements in research and development as well as facilitating economic growth (Irfan et al., 2022). The P-values for the first-order autoregressive (AR (1)), second-order autoregressive (AR (2)), and Hansen test in this model satisfy the necessary criteria.

In model (3b), the final step examines the extent to which both the independent variable (green finance) and the mediating variable (green technology innovation) have a substantial influence on the dependent variable (green economic growth). The regression analysis shows that the coefficient of green finance on green economic growth is 0.004, which is statistically significant at the 0.1 level. This indicates that 0.004 units of green economic growth can be attributed to one unit of green finance. Simultaneously, the correlation coefficient between green technology innovation and green economic growth is 0.004, which also meets the criteria for statistical significance at the 0.1 level. This suggests that one unit of increased green technology innovation can lead to 0.004 units of increased green economic growth. This may be because green technology innovation decreases pollution and environmental damage through the innovation of technology, processes, and environmental protection materials (Sharma et al., 2021) and ensures that technological innovation has the least adverse effects on the environment as feasible (Liu et al., 2021). The P-values for the first-order autoregressive (AR (1)), second-order autoregressive (AR (2)), and Hansen tests in this model all satisfy the appropriate statistical criteria.

Table 4.14: Results of mediating effect of green technology innovation

Variable	Model (1)	Model (3a)	Model (3b)
	GEG	GTI	GEG
GEG_{it-1}	0.763***		0.994***
	(0.160)		(0.058)
GTI_{it-1}		0.629***	
		(0.121)	
GTI			0.004*
			(0.002)
Green finance	0.007***	0.275**	0.004*
	(0.002)	(0.112)	(0.002)
Covid-19	-0.002	-0.200***	0.005
	(0.006)	(0.071)	(0.003)
FD	0.040*	0.164	0.001
	(0.024)	(0.120)	(0.005)
Education	0.555*	3.952	0.132*
	(0.305)	(2.525)	(0.080)
Urbanisation	-0.080	0.606	-0.012
	(0.052)	(0.536)	(0.032)
_cons	-0.162**	-1.553*	-0.045**
	(0.076)	(0.831)	(0.018)
N	756	756	756
AR(1)	P=0.013	P=0.001	P=0.006
AR(2)	P=0.484	P=0.124	P=0.590
Hansen test	P=0.490	P=0.449	P=0.348

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Overall, this study presents a comprehensive compilation of the results from the mediating effect of green technology innovation, as displayed in Table 4.14. Based on the stepwise regression method, the initial step reveals that green finance has a significant positive impact on green economic growth (beta=0.007, P<0.01) in model (1). In model (3a), the second step demonstrates that green finance has a significant impact on the mediating variable of green technology innovation (beta=0.275, P<0.05). In model (3b), the third step reveals that both green finance and green technology innovation have a statistically significant impact on green economic growth. The coefficients for green finance and green technology innovation are 0.004 (P<0.1) and 0.004 (P<0.1), respectively. The results suggest that the development of green technology plays an important role in linking green finance and green economic growth. Therefore, this study concluded that Hypothesis 3 is accepted, which states that green technology innovation acts as a mediator between green finance and green economic growth.

4.10.2 Robust Test of Objective 3

This study employs the modified Sobel test, employing a fixed effect model, to thoroughly investigate the mediating impact of green technology innovation. Table 4.15 clearly demonstrates that green finance has a substantial impact on promoting green economic growth, as indicated by a coefficient (beta) of 0.006 ($p<0.01$) in Column (1). In Column (2), the coefficient of green finance on green technology innovation is 0.209, which is statistically significant at the 0.01 level.

In addition, both the independent variable (green finance) and the mediating variable (green technology innovation) have a positive and significant impact on the dependent variable (green economic growth) in Column (3), with coefficients of 0.004 ($p<0.05$) and 0.013 ($p<0.01$), respectively. The revised Sobel test findings validate that green technology innovation successfully satisfies the Sobel test ($z=4.845$, $p<0.01$), with the indirect impact constituting 43.52% of the overall effect. These findings suggest that 43.52% of the influence of green finance on green economic growth is channelled through green technology innovation.

Table 4.15: Results of robust test for objective 3

Variable	(1)	(2)	(3)
	GEG	GTI	GEG
GTI			0.013***
			(0.002)
Green finance	0.006***	0.209***	0.004**
	(0.002)	(0.027)	(0.002)
Covid-19	0.006***	-0.465***	0.034***
	(0.002)	(0.055)	(0.003)
FD	0.023***	0.783***	0.013***
	(0.004)	(0.065)	(0.004)
Education	0.688***	2.441*	0.656***
	(0.080)	(1.330)	(0.078)
Urbanisation	0.405***	6.881***	0.315***
	(0.044)	(0.732)	(0.045)
_cons	-0.279***	-5.488***	-0.207***
	(0.033)	(0.553)	(0.034)
Sobel test		z=4.845***	
Indirect effect		z=4.845***	
Direct effect		z=2.202**	
Total effect		z=3.959***	
Proportion of indirect effect		43.52%	

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

In summary, the findings of the modified Sobel test indicate that the introduction of green technology innovation has a beneficial role in linking green finance and green economic growth. Therefore, the conclusions are strong and reliable.

4.10.3 Discussion of Objective 3

As previously mentioned, this study discovered that the introduction of green technology innovation plays a positive and significant role in connecting green finance and green economy in developed countries, with the indirect effect accounting for 43.52% of the total effect. The outcomes are consistent with the Porter Hypothesis Theory. It suggests that environmental regulation can signal inefficiencies in resource allocation and the need for technological advancement, which promotes the "innovation compensation" effect, ultimately leading to environmental advantages through enhanced production (Porter & Van der Linde, 1995). Hence, this study provides confirmation that the implementation of green finance legislation can successfully encourage innovation in green technology within organisations, therefore encouraging their engagement in green innovation activities. Green finance not only directly promotes green economic growth but is also strengthened through the mediation of green technology innovation. Green technology innovation decreases the use of fossil fuel and enhances the consumption of clean energy by creating new equipment and processes. This has a positive impact on the environment and helps preserve resources. Moreover, the implementation of green technology fosters the improvement of production efficiency in firms through continuous innovation.

Previous research has found green technology innovation enhances green economic growth in developed and developing countries (Ikram et al., 2021; Mahmood et al., 2022). However, no studies have investigated the mediating role of green technology innovation in the link between green finance and green economic growth. Related research has revealed the mediating role of technological innovation in the negative impact of financial development on carbon emissions in China (Ji et al., 2022). This implies that financial development contributes to the reduction of carbon emissions through the mediating effect of technological innovation. The differences between this related research and the current study are substantial and can be outlined as follows: (1) The current study focuses on the mediating role of green technology innovation, emphasising both environmental conservation and economic benefits, distinguishing it from general technological innovation in previous research. (2) In contrast to financial development, green finance in this study is more reflective of environmental policies than profit considerations alone. (3) Green economic growth in this study encompasses a wider range of goals, including promoting environmental, economic, and social progress, rather than just reducing carbon emissions in the related research. These distinctions suggest that the current study has done a more comprehensive and detailed investigation, as this related study has not focused on green finance and green technology innovation, which can simultaneously gain environmental and economic benefits.

Furthermore, although empirical results demonstrate the contribution of green technology to green economic growth in both developed and developing nations (Ikram et al., 2021; Mahmood et al., 2022), notable differences exist in the application and efficacy of green technology innovation in these two groups. This highlights the importance for different countries to formulate differentiated policies of green technology to achieve green economic growth. Fossil fuel consumption is acknowledged as a primary cause of the greenhouse effect due to the substantial amounts of carbon emissions (Martins et al., 2021). And green technology innovation is the key measure to accelerate the structural transformation of energy consumption and reduce carbon emissions (Dong et al., 2022).

Data from the Global Carbon Atlas, shown in Figure 1.3, reveals that carbon emissions in OECD countries exhibited a slow decrease from 1995 to 2022. Scholars also find that developed countries have effectively improved environmental quality through the use of advanced technology, resulting in a substantial decrease in carbon emissions and an enhancement of ecological conditions (F. Wang et al., 2023). The development of green technology innovation plays a crucial role in attaining carbon reduction goals by promoting the use of clean energy and replacing the consumption of fossil fuels, which are the primary contributors to carbon emissions (Yin et al., 2022).

In contrast, carbon emissions in Asian countries, as illustrated in Figure 1.3, show a rapid upward trend. Based on statistics from the World Bank database, China, the largest developing country, has seen a sharp increase in carbon emissions during this period, and the same is true for India. This illustrates the fact that developing countries are lagging far behind developed countries in terms of clean energy use and carbon reduction. In order to achieve significant reductions in carbon emissions, it is crucial for developing countries to prioritise the adoption and implementation of green energy technology, which is currently at relatively low levels.

After the empirical test in this study, the summary of results of all hypotheses is shown in Table 4.16.

Table 4.16: Summary of hypothesis test results

Number	Hypothetical content	Test results
H1	Green finance has a positive effect on green economic growth. turnover intention	Accepted
H2	Industrial structure upgrading positively mediates the relationship between green finance and green economic growth.	Accepted
H3	Green technology innovation positively mediates the relationship between green finance and green economic growth.	Accepted

4.11 Summary

In this chapter, the study investigates the effects and ways in which green finance influences green economic growth. It validates the hypotheses using different statistical models and tests to ensure the results are reliable. The results suggest that green finance has a substantial impact on promoting green economic growth, as evidenced by various statistical models, including pooled OLS, two-way fixed effect, random effect, fixed effect, 2SLS, and System GMM models. The study confirmed the mediating effect of industrial structure upgrading using stepwise regression and the modified Sobel test. The results indicated that 8.94% of the impact of green finance on green economic growth is mediated by industrial structure upgrading. Furthermore, the study found that green technology innovation plays a mediating role in the relationship between green finance and green economic growth. The results of the Sobel test revealed that 43.52% of the impact of green finance on green economic growth is transmitted through green technology innovation. These findings emphasise the significance of implementing green financial policies and advancements in order to attain sustainable economic growth.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter concludes the study by providing a concise overview of the findings, highlighting their theoretical and practical significance, and offering recommendations based on the key results. Section 5.2 provides a thorough overview and conclusion, combining the main findings and emphasising the fundamental results of the study. Section 5.3 examines the study's contributions from both an academic and practical standpoint. From an academic standpoint, it elucidates how the discoveries propel the progress of current knowledge and hypotheses in the respective area. Essentially, it showcases the practical use of the findings in real-life situations, highlighting their potential advantages for professionals in the sector and their ability to guide the development of optimal methods.

Section 5.4 examines the constraints faced during the research process and explores how these restrictions may affect the applicability of the findings. This section additionally presents recommendations for future research, indicating specific areas where further research could expand upon the current work and fill any detected deficiencies. To summarise, this chapter combines the essential components of the study, offering a comprehensive perspective on its contributions and implications and also setting the stage for further academic investigation and practical implementation.

5.2 Summary and Conclusion

This study aims to investigate the impact of green finance on green economic growth, specifically examining how industrial structure upgrading and green technology innovation mediate this relationship. The study's sample population consists of developed countries that have seen a shift from fast industrialisation, frequently accompanied by substantial pollution, to a renewed focus on green economic growth. By analysing wealthy countries, the results are expected to provide stronger conclusions and practical insights that can be applied to underdeveloped countries.

The study confirms that green finance, upgrading industrial structures, and innovation in green technology play a crucial role in promoting green economic growth in developed countries. More precisely, it confirms that green finance contributes to promoting green economic growth, which is consistent with the Green Finance Theory. This is because the theory advocates the provision of financial support for green projects to gain environmental benefits, such as carbon reduction and resource conservation. Although other researchers have produced contradictory or differing findings due to differences in perspective or transmission mechanisms, this conclusion reaffirms that nations with higher levels of green finance have higher levels of green economic growth.

Additionally, the analysis uncovers that industrial structure upgrading has a positive and significant mediating impact on the correlation between green finance and green economic growth, constituting 8.94% of the overall effect.

The statement clarifies that green finance promotes the shift towards more sustainable industrial systems, thereby enhancing green economic growth. These findings highlight the importance of using industrial upgrading tactics that are in line with the urgent need for environmental sustainability. Previous studies have regarded industrial structure upgrading as a mediator in other relationships, such as the link between financial development and carbon emissions. As prior industry-related studies have not addressed this specific application, the results of this paper go more deeply into the mediating role of industrial structure upgrading in the impact of green finance on green development compared with the previous ones.

Besides, the study highlights the positive and significant mediating role of green technology innovation in linking green finance and green economic growth. It attributes 43.52% of the influence of green finance on green economic growth to this mediating relationship. Green finance acts as a catalyst for promoting innovation in green technology, which in turn stimulates sustainable economic growth. This highlights the need for wealthy and poor countries to give importance to investments and policies that promote the development of innovative green technology in order to support long-term environmental and economic sustainability. Although empirical results demonstrate the contribution of green technology to green economic growth in both developed and developing nations, there are notable differences in the application and efficacy of green technology innovations in these two groups. Green technology innovation is a key measure to accelerate the structural transformation of energy consumption and reduce carbon emissions (Dong et al., 2022). As shown in Figure 1.3, carbon emissions in Asian nations show a sharp increase, while those in the OECD showed a gradual decline from 1976 to 2022. This indicates that the transformation and application of green innovation in developing nations is far behind those in developed ones. Therefore, it is crucial for developing countries to pay attention to the role of green innovation in solving energy consumption and environmental pollution so as to rapidly promote green economic growth.

The study's findings offer unique insights into how green finance can promote green economic growth, emphasising the important mediating roles of upgrading industrial structure and innovating green technologies in this relationship. These insights provide practical suggestions for policymakers, companies, and stakeholders to create policies that support sustainable economic development goals.

5.3 Contribution of the Study

The results revealed in this study greatly enhance our understanding of the relationship between green finance and green economic growth. It clarifies how industrial structure upgrading and green technology innovation play a mediating role in this relationship. These contributions are especially remarkable from both an academic and practical perspective.

5.3.1 Theoretical Contribution

(1) This study fills a significant gap in the existing literature by developing a thorough theoretical framework that explains the influence of green finance on green economic growth. Prior studies have mainly concentrated on defining green finance and analysing its impact on environmental sustainability and resource management. Even though previous studies have examined the separate relationship among green finance, industrial structure upgrading, and green technology innovation (Su & Fan, 2022b; L. Wang et al., 2022; Yang et al., 2021; G. Zhou et al., 2022), these investigations have often been incomplete, lacking a comprehensive framework that integrates all these factors holistically (Fehr et al., 2004). Therefore, there is a limitation to studies that examine the combined effects of green finance, industrial structure upgrading, green technology innovation, and their interconnections on green economic growth. This study aims to fill this gap by developing a theoretical framework that not only explains the direct impact of green finance on green economic growth but also describes the mediating effects of upgrading industrial structure and innovating green technologies. The empirical results of this study confirm the proposed theoretical framework, therefore enhancing and broadening the current knowledge in this field.

(2) This study makes a methodological contribution by creating a thorough index for assessing green economic growth utilising the entropy-weighted TOPSIS technique. Previous studies on green economic growth have frequently used single indicators or limited techniques, which might result in a

narrow viewpoint and a lack of comprehensive evaluation of sustainability (Fehr et al., 2004). This study also presents a new index that aims to measure green economic growth. The index consists of four dimensions and eleven variables, which are listed in Table 4.1. This analytical breakthrough improves the precision and inclusiveness of evaluating green economic growth, therefore enabling better-informed policy choices and sustainable development strategies.

(3) The findings of this study also provide evidence for the mediating effects of industrial structure upgrading and green technology innovation on the relationship between green finance and green economic growth. The relationship is positively influenced by industrial structure upgrading, which accounts for 8.94% of the overall effect. Green finance incentivises the shift towards tertiary businesses with more value-added and lower pollution levels, fostering green economic growth. Green technology innovation plays a crucial role in mediating 43.52% of the influence of green finance on green economic growth. Green finance promotes the use of clean energy sources and reduces environmental damage by encouraging investments in research and development of ecologically friendly technology. This, in turn, supports sustainable economic growth. The empirical findings emphasise the various ways in which green finance impacts green economic development. They highlight the significance of comprehensive policy frameworks that encourage technological innovation and industrial restructuring, in addition to providing financial support for sustainability initiatives.

5.3.2 Practical Contribution

First, the implementation of the Green Economic Growth Index provides countries with a great instrument to evaluate and track their advancement towards sustainable development goals. Governments can adopt this index to analyse the efficacy of their environmental policies and efforts, acting as a vital standard for evaluating regional performance in sustainable development. The Green Economic Growth Index offers a solution to the challenges faced by developing countries that are rapidly industrialising, as they balance economic growth with environmental sustainability. It serves as a tool to address the negative effects of resource depletion and pollution on a global level. Developing countries should steer their development paths towards more sustainable routes by giving priority to green economic growth. This approach will help protect environmental resources and ensure long-term human well-being.

Second, this study emphasises the significance of developing customised strategies to promote green economic expansion. Policymakers are advised to actively encourage public knowledge of green development concepts and environmental conservation, thus establishing the foundation for sustainable consumption and investment practices. Establishing resilient green development frameworks and promoting green investments are crucial measures for fostering a green financial ecosystem that supports sustainable economic expansion. Furthermore, it is crucial to provide specific assistance for the improvement of industrial structures, which can be achieved through the implementation of green finance methods. This will help guide economies towards more environmentally friendly and robust paths. Encouraging the development of green technology is extremely important. This requires cooperation between businesses, research institutions, and markets to promote technical changes that support sustainable growth.

Third, this study presents concrete policy suggestions specifically for developing nations that are facing the intertwined obstacles of achieving economic growth while safeguarding the environment. Emerging economies are advised to find a middle ground between economic growth and environmental protection. This involves prioritising and efficiently using green funding to stimulate green enterprises. Moreover, it is important to make concentrated endeavours to expedite the acceptance and spread of environmentally friendly technology and motivate creativity through tax incentives and supporting regulations. These programs seek to speed up the shift towards sustainable development paths, reducing the negative environmental effects linked to fast industrialisation.

Fourth, firms are advised to take advantage of green policy subsidies to promote the development of green technologies, thus improving their competitive edge and promoting sustainable development practices. Green technology innovation plays a crucial role in connecting green finance and economic growth. Firms can gain advantages by matching their technological skills with the increasing need for environmentally friendly solutions. By allocating resources to the development of environmentally friendly technology, businesses can enhance their ability to compete in the market and support environmental sustainability objectives. This will ensure their long-term success in a rapidly changing business environment.

Fifth, investors also have the chance to expand their portfolios and take advantage of the growing green investing market. Green investment projects, which are defined by their adherence to both economic and environmental goals, provide investors with the opportunity to achieve long-term profits while also supporting broader sustainability initiatives. With the growing emphasis on environmental concerns by governments and consumers, green investments are expected to become more popular. This offers investors an attractive opportunity to generate positive returns on their investments while also promoting sustainable development goals.

5.4 Limitation of the Study

Although the study offers essential insights, it is crucial to recognise its limitations in order to guide practical approaches and emphasise potential areas for future investigations. A major constraint of this study was its sample selection. The study concentrates on panel data obtained from 28 developed countries that have shifted from periods of fast industrialisation and high levels of pollution to prioritising green economic growth. This choice improves the credibility of the findings and reinforces the suggestions, making them applicable not only to developed countries but also as valuable sources of information for developing countries. Nevertheless, the study might have been enhanced by a more extensive examination that incorporated developing countries to provide a comparative viewpoint. The exclusion of developing countries is mostly attributed to practical limitations, such as the absence of consistent statistics on green finance and the lack of standardised and comprehensive data collections in these countries. Additionally, data on green technology innovation, particularly the number of green patents, was insufficient for developing countries, further limiting the scope of the sample.

Another constraint relates to the extent of components taken into account in the analysis. This study investigates the impact of green finance, industrial structure upgrading, and green technology innovation on green economic growth. However, it does not consider other possibly influential factors. Political issues such as environmental levies, economic openness as indicated by foreign direct investment (FDI), and energy consumption structures are excluded. These factors may have significant effects on the expansion of the green economy and should be taken into account in future studies to gain a more comprehensive knowledge of the underlying dynamics.

In addition, the technique used in this study largely emphasises quantitative empirical analysis and lacks qualitative analysis. The study utilises quantitative approaches to examine ideas on the influence of green finance on green economic growth, as well as the mediating effects of green technology innovation and industrial structure upgrading. Nevertheless, the qualitative component of the research is not incorporated in this study, encompassing surveys and interviews, due to inadequately developed instruments.

Integrating qualitative research methodologies would yield more profound insights into the subjective experiences and perceptions associated with green finance and economic growth, enhancing the empirical findings with contextual comprehension.

Recognising these constraints is essential for informing future research trajectories. To improve the comprehensiveness and applicability of findings in the field of green finance and green economic growth, it is important to include developed countries in the sample, consider a wider variety of influential factors, and use qualitative research methodologies. These enhancements would not only enhance the theoretical framework but also offer additional practical insights for policymakers and stakeholders worldwide.

5.5 Recommendation for Future Research

Recognising the limitations of this study creates opportunities for future research, allowing for more extensive analysis and broader findings. This study outlines three crucial areas that require additional investigation to improve the comprehension and practicality of green financing, green technology innovation, industrial structure upgrading, and green economic growth.

First, it is recommended that future studies augment the sample by incorporating data from developing countries in order to conduct a more exhaustive analysis. The findings and recommendations of this study are relevant not only to developed countries but also provide useful insights for developing countries. Nevertheless, as a result of constraints in data collection, this study solely relied on data obtained from developed countries.

To fill this gap, future research might use samples from developing countries or amalgamate data from both developed and developing countries for comparative analysis. Implementing such a method would assist in verifying the wider suitability and significance of the study on green finance and its effects in other economic settings, therefore strengthening the reliability of the derived conclusions.

Second, it is suggested that future research investigate the impact of supplementary elements, such as political, openness, and energy considerations, on the expansion of the green economy. The main emphasis of this study was on green finance, green technology innovation, and industrial structure upgrading. However, other important aspects were not taken into account. An in-depth analysis of political factors, such as environmental legislation and taxation, openness elements like foreign direct investment (FDI), and energy considerations associated with consumption patterns could offer a more comprehensive understanding of the forces that drive green economic growth. This thorough research would enhance the existing body of knowledge on environmental governance and sustainable development, providing policymakers with more profound insights.

Third, future research has the potential to greatly enhance the scope of qualitative analysis. By adopting techniques like questionnaires or interviews with influential individuals such as legislators, businesses, and investors, it can gain useful insights into topics such as green economic growth, sustainable financing, innovative green technologies, and the improvement of industrial structures. To enhance the empirical findings, it would be beneficial to gain insight into how firms have been supported by governmental and financial institutions in terms of green finance, how they have utilised finance for green technology research and development, and how they have practically implemented green technologies. Qualitative data would provide a deeper knowledge of the mechanisms and effectiveness of green finance and related policies, giving a more comprehensive perspective on the problems and opportunities in supporting green economic growth.

In general, incorporating these suggestions into future studies would greatly enhance the subject of green finance and promote sustainable economic growth. To enhance the comprehensiveness and applicability of future studies, it is recommended to broaden the sample to include developing countries, take into account additional significant factors, and incorporate qualitative analysis. This will not only enhance theoretical understanding but also provide practical, implementable suggestions for policymakers and stakeholders seeking to promote sustainable development on a global scale.

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BIODATA OF STUDENT

The author earned his undergraduate degree in marketing in 2012 and his master's degree in finance in 2015. He has previously served as a lecturer at Wuhan College of Arts and Sciences. His research includes green finance, green development, international trade, and global value chain embedding. He has published two papers in journal of cleaner production.

LIST OF PUBLICATIONS

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