CAPITAL UNIVERSITY OF SCIENCE AND TECHNOLOGY, ISLAMABAD

Unlocking Sustainable Growth: The Mediating Role of Renewable Energy and Moderating Impact of Green Technology in the Green Finance– Economic Growth Nexus

by

Shafaq Zafar

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This research thesis is wholeheartedly dedicated to my late father who gave me confidence to aim high in life and my mother whose support and continued encouragement have been my strength and source of inspiration in all of my endeavors.

CERTIFICATE OF APPROVAL

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by

Shafaq Zafar

(MAF231001)

THESIS EXAMINING COMMITTEE

S. No.	Examiner	Name	Organization
(a)	External Examiner	Dr. Aijaz Mustafa Hashmi	NUML, Islamabad
(b)	Internal Examiner	Dr. Anum Rashid	CUST, Islamabad
(c)	Supervisor	Dr. Jaleel Ahmed Malik	CUST, Islamabad

Dr. Jaleel Ahmed Malik
Thesis Supervisor
August, 2025

Dr. Jaleel Ahmed Malik
Head
Dept. of Accounting and Finance
August, 2025

Dr. Arshad Hassan
Dean
Faculty of Management & Social Sci.
August, 2025

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(Shafaq Zafar)

Abstract

The aim of this study is to investigate the moderated mediation effect of green finance on economic growth through renewable energy, with green technology as a moderating variable in developing economies. The sample comprises 80 developing countries out of the total 266 countries and these countries are chosen based on data availability. The annual panel data of all these countries is used in the analysis, spanning from 2000 to 2021. The econometric technique, Structural Equation Modeling (SEM), is used for data analysis. Data is retrieved from World Development Indicators, Our World in Data and the Organization for Economic Cooperation and Development (OECD). The findings reveal that green finance has a positive and significant impact on both economic growth and renewable energy. Renewable energy exerts a positive influence on economic growth and mediates the relationship between green finance and economic growth. Moreover, green technology plays a moderating role by strengthening the direct effect of green finance on renewable energy and the indirect effect of green finance on economic growth through renewable energy. These findings underscore the importance of integrated green policies that promote financial investment, technological innovation and sustainable energy infrastructure to achieve economic growth in developing economies.

Keywords:Green Finance, Economic Growth, Renewable Energy, Green Technology, Structural Equation Modeling

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Abbreviations

EG	Economic Growth
ER	Exchange Rate
GF	Green Finance
GT	Green Technology
RE	Renewable Energy
SEM	Structural Equation Modeling
TO	Trade Openness

Chapter 1

Introduction

1.1 Background of the Study

In recent decades, the world has undergone drastic changes in climate and environmental degradation, largely driven by the relentless rise in anthropogenic activities and fossil fuel consumption (WMO, 2024; IPCC, 2023). To address this issue, the international community, through the Paris Agreement, has committed to set ambitious targets to reduce CO_2 emissions.

Despite these commitments, greenhouse gas emissions escalated by 11% and carbon emissions climbed up to 41.6 billion tonnes in 2024 (Praveen, Rath, & Akram, 2025). UN proposed 17 Sustainable Development Goals in 2015, which serve as a guidance tool for achieving Sustainable Development targets around the globe by 2030.

The escalation of ecological threats, including pollution, biodiversity depletion and climate change has catalyzed global initiatives aimed at promoting sustainable development in the 21st century. Such a pattern highlights the necessity for a revolutionary paradigm regarding economic growth (EG) that decouples growth from ecological deterioration.

These impacts have been especially pronounced in developing economies where industrialization and economic growth mostly occur at the cost of the environment. However, SDG 13 highlights the necessity for immediate action concerning climate change and SDG 8 suggests to promote economic growth (UnitedNations, 2025).

In this regard, the integration of green finance (GF), renewable energy (RE) and green technology(GT) delineates a revolutionary approach towards the attainment of goal 8, executed in a manner that is ecologically sustainable and economically equitable. Green finance is a financial mechanism that aids enterprises and can be advantageous for both the environment and the economy. It is a financial instrument evolved to address environmental challenges and enhance the quality of the environment (Qing, Abbas, Najam, Ma, & Dagestani, 2024). Many scholars have argued that green instruments including green bonds, green loans can generate employment, maximize growth in national economies while mitigating greenhouse gas emissions(GHG) and addressing environmental and social challenges (H. Huang, Huang, & Sun, 2023). In 2020, New York Green Banks issued green bonds amounting to $16 billion, facilitating an investment of 360 million dollars in 2019, that are anticipated to mitigate 743,000 tons of GHG emissions approximately. However, in 2018 The European Commission published an action plan which encourages the growth of green projects by offering government guarantees, tax breaks and other incentives.

However, it serves as an opportunity for developing countries with climate vulnerabilities and deficiencies in infrastructure to not only provide climate funding, but also enhance financial stability, increase employment opportunities and boost the upgrading of industries. Banks encourages green growth by declining the fund that are ecologically damaging projects in addition to offering green loans. Investors are concerned about potential cost and benefits; they want portfolio diversification through investing in securities that are environmentally friendly (Nie, Yao, & Feng, 2024).

According to Kuznets (1973) growth in economy is termed as the development of country in providing goods to the people and satisfying all the demands.Attainment of economic growth in developing nations remains a paramount objective in the realm of development (Acemoglu, 2008). Since the 1950s, due to economic growth, rise in population, technological advancements and rapid urbanization fosters renewable energy requirements with time.

The International Energy Agency (IEA) defines renewable energy as coming from natural processes that replenish more quickly than they are used. Renewable

energy sources will generate for 42% of the global energy by 2028, with solar and wind energy making up 25% of this total. Developing economies are expected to be responsible for a 74% increase in the demand of energy globally during that period. By 2050, it is anticipated that 2/3rd of the energy supply will be from renewable sources (International Renewable Energy Agency (IRENA), 2020).

Moreover, the Renewable Energy Directives were introduced by the European Union in 2018 with the aim of increasing the proportion of renewable energy to 32% by 2030.

In alignment with SDG7, which ensures that all people have access to sustainable energy. It recognizes that access to clean energy is central to reducing poverty, generating jobs and transforming the economy.

Spending on sustainable energies frequently encourages the expansion of regional manufacturing by expanding the capacity of industries. Gradually, renewable energy technologies are becoming cheaper as compared to conventional sources of energy that lowers the expenses for household and consumers.

The latest conference summit, COP 29, set goals to double the installed capacity of renewable energy globally by 2030 (Nepal, Liu, Wang, & Dong, 2024). Combustion of fossil fuels is mainly responsible for carbon dioxide (CO_2) in the environment. The detrimental effects on the environment caused by global warming and greenhouse gases made people worry about using fossil fuels.

As a result, renewable energy sources are becoming a pivotal element in global energy consumption. Clean energy sources are advantageous in abating carbon dioxide and pollution contributes significantly to the protection of the environment. However, due to its high cost, switching can be challenging for developing countries, as building and maintaining the infrastructure for renewable energy is more expensive.

To make this transition smoother, a strong financial framework is needed that can provide financial assistance by making sure there are enough money in market. Nations are finding it challenging to shift towards green energy due to insufficient funding from business sectors. Hence, the main obstacle to the global implementation of renewable energy is a lack of investment in the public and private sector.

Discussions at COP26 emphasized the developing nations to secure financial and technological transfers through the utilization of Renewable Energy (Nie et al., 2024).

Additionally, investors found out that renewable energy projects as riskier with lower return on investments. However, the cost of these projects have significantly decreased due to advancements in environmentally friendly technologies and decreased rate of funding provided by green financing. Reduced funding cost could accelerate the shift towards renewable energies (Bilal & Shaheen, 2023). Long term financing of RE projects can be effectively facilitated by green bonds and other green financial instruments that lead to abate the GHG emissions (Rasoulinezhad & Taghizadeh-Hesary, 2022). Moreover, Climate Bond Initiative (CBI,2023) reports that renewable energy segment usually has the highest proportion in allocation of global green bonds at more than 30% of proceeds use in the majority of developing economies.

In essence, contribution of green finance (GF) to economic growth is mediated by accelerated adoption of renewable energy. Consequently, through the provision of accessible and strategically directed financial resources, green finance empowers developing countries to surmount, financial obstacles thus promoting the extensive implementation of clean energies (Alharbi, Al Mamun, Boubaker, & Rizvi, 2023). This impact is optimally achieved through implementation of renewable energy technologies which function as a conduit through which environmentally sustainable financial instruments that are quantifiable in developmental results.

As a response to the escalating worldwide concern regarding the environment, green technology that encompasses, broad array of products and practices are designed to reduce environmental harm and that promote ecological sustainability. SDG 9 is linked to technological development tend to emphasize on innovation and infrastructure. Generally speaking, green technology also termed as sustainable technology and eco-friendly technology is the use of science and technology to produce environmentally friendly products i.e., renewable energy, waste management, sustainable transportation. It is anticipated to generate double dividend by reducing environmental stress as well as conducive towards economy's technological advancement and a fundamental contributor in economic development (Q. Wang,

Qu, Wang, Wang, & Yang, 2019). It is found out that different green financing instruments have impact on green technology i.e., green bonds (G. Wang et al., 2022), green credit (He et al. 2019) that contributes towards investment in green technology.

Furthermore, investments in green financing instruments can have a substantial influence and speed up the transition if clean energy projects are more feasible due to contribution of escalated levels of GT efficiency and viability of clean energy projects can be improved by advancements in the efficiency of energy, innovative systems of clean energy and smart grids.

In our perspective, economic growth likely influences the path of green financing in determining how renewable energy is intervening. This study is mainly focused on ascertaining the moderated mediation effect i.e. the indirect effect of green finance alongside economic growth via renewable energy.

Analyzing the combined effect of several variables that influence the outcome simultaneously is essential to gain deeper insights of the variables. However, it is the novel contribution to the literature of finance as it unravels the explored perspectives associated with green finance, renewable energy, green technology and economic growth.

1.2 Theoretical Background

The nexus between the variables of this study can be understood through numerous theoretical frameworks. A few key theoretical foundations underpin the linkages among these factors. This study employs several theories i.e., Financial Intermediation Theory, Neoclassical Growth Theory, and Environmental Kuznets Curve Hypothesis to investigate the indirect effect of renewable energy on the moderating role of green technology between green finance and renewable energy.

1.2.1 Financial Intermediation Theory

The theory of financial intermediation was credited to Gurley and Shaw (1960) and further refined by scholars like Douglas Diamond (1984). This theory advocates

that developed financial sector boosts economic growth by efficiently allocating savings to productive investments. In the realm of developing nations, Shaw (1973) and McKinnon (1973) further elucidated the pivotal role that efficient financial systems play in fostering capital accumulation and facilitating steady growth in the economy by uplifting the investments levels and raising efficiency in allocating funds.

Financial intermediaries transform the maturity structure of assets and liabilities by matching the preferences of savers and buyers. The framework is aligned with green finance, it serves as a financial intermediary where financial institutions and instruments channel capital flows into renewable projects by minimizing financing gaps and reducing the risks pertaining to green investments. As a result, deployment of RE acts as a mechanism through which sustainable financing boosts the growth in the economy. Moreover, the existence of environmentally friendly technologies complements this process by raising the efficiency and productivity of such investments.

1.2.2 Neoclassical Growth Theory

Neoclassical growth theory posits that the phenomenon of economic growth is driven by three forces: labour, capital and technological advancement. The National Bureau of Economic Research accredits the formation and development of the long term economic growth model to contribution of Solow (1956) and Swan (1956). Initially, the exogenous population was taken into consideration for determining the growth rate. Solow included technological change to the model in 1957. However, neoclassical growth theory states that temporary equilibrium is a result of varying amounts of labour and capital in the production function. It is also articulated that technological advancements have substantial influence on an economy. In this framework, green finance not only functions as a capital but also acts as an investment that contributes to the mobilization of green capital in the economy, especially in the form of renewable energy and development of environmentally friendly technologies. This investment drives the total stock of capital and importantly changes its composition to more efficient and sustainable forms. Renewable energy thus serves as a particular, cleaner energy input which raises

the productivity of labor and capital in the production function, intermediating the influence of green finance on GDP through delivering a more consistent, environmentally friendly and possibly the cheap supply of energy. Moreover, the green technology an endogenous driver of innovation and knowledge making greener capital more efficient, lowering the cost propels the function of production upward.

1.2.3 Environmental Kuznets Curve (EKC) Hypothesis

The formulation of EKC theory is credited to Simon Kuznets (1955) who articulates a curvilinear association between various indicators of pollution and GDP. Initially, when economies are developed, it leads to increased levels of pollution and environmental deterioration. When a nation reaches a certain level of economic development, there might be a decoupling between GDP growth and environmental effects. This can be attained through opting environmentally friendly technologies, maximizing energy efficiency, and switching to cleaner and renewable energy sources, all of which support long term economic growth. It is critical to keep in mind that the actual causal relationships and degree of impacts might be different from country to country, regions and time periods, necessitating empirical analysis and study that is particular to the situation to better understand these relationships.

1.3 Problem Statement

The shift towards a sustainable economy necessitates strong financial frameworks, technological evolution and effective utilization of energy resources. Numerous scholars have studied the nexus between green finance, economic growth, renewable energy, and green technology, but the findings of these empirical studies are inconclusive (Sampene et al., 2024; Zhang, 2022). This study extensively analyzes the mediating role of renewable energy between green finance and economic growth, the moderating role of green technology between green finance and renewable energy and its influence on the indirect impact of green finance on economic growth. Moreover, none of the studies examined a particular nexus using a moderated mediation framework and SEM approach.

1.4 Research Questions

1. What is the impact of green finance on economic growth?

2. What is the impact of green finance on renewable energy?

3. What is the impact of renewable energy on economic growth?

4. Does renewable energy mediate between green finance and economic growth?

5. Does green technology moderate between green finance and renewable energy?

6. Does green technology moderate the indirect effect of renewable energy on economic growth?

1.5 Research Objectives

1. To study the impact of green finance on economic growth.

2. To study the impact of green finance on renewable energy.

3. To study the impact of renewable energy on economic growth.

4. To study the mediating role of renewable energy between green finance and economic growth.

5. To study the moderating role of green technology between green finance and renewable energy.

6. To study the moderating role of green technology on the mediating effect of renewable energy between green finance and economic growth.

1.6 Significance of Study

This research provides valuable insights on the interconnection among green finance, renewable energy, green technology and economic growth. The study findings will serve as a guideline for countries to achieve the SDGs goals and the Paris Agreement. The outcomes of the study will help policymakers to maximize green finance initiatives through formulating environmentally friendly policies, i.e.; tax

benefits and subsidies that aid in renewable energy investments. Investors can benefit from insights that green finance strengthens green technology when accompanied by renewable energy and influences economic development by minimizing costs. This understanding provides guidance on portfolio diversification, risk assessment and the importance of sustainable investments. The government may find research useful to implement policies to widen the advantages of green technology on economic growth through offering grants to businesses engaged in the investment of green technologies. Additionally, governments can enforce regulatory frameworks to promote economic growth and minimize the impacts of environmental degradation. Moreover, enterprises can boost their productivity through incorporating green technologies. This study makes an academic contribution to the literature by providing a deeper understanding of association among green finance, economic growth, renewable energy, green technology and economic growth. It can serve as a foundation for future research directions that are unexplored.

1.7 Study Scheme

The research thesis has been organized into five sections. The first chapter introduces the research topic and provides details on the background of the study, including the problem statement, research questions, research objectives, and the significance of the study. The second chapter comprises existing literature on the relationship between variables, hypothesis, and research model. The third chapter encompasses the sample of the study, description of variables, data, its sources and methodology. In Chapter 4, results and discussion are mentioned. The last chapter comprises of conclusion, recommendations, and directions for the future research.

Chapter 2

Literature Review

The literature review aims to integrate the existing literature to provide meaningful insights into our variables. The contributions of the previous scholars, their findings and the theoretical underpinnings related to the study are discussed.

2.1 Impact of Green Finance on Economic Growth

Green finance has gained recognition due to its intertwined environmental and economic challenges of the modern world. It has emerged as a financial instrument that focuses on the financial impact of ecological changes across various businesses and sectors, highlighting the need to transform the traditional economy by attaining the target of net zero emissions (Jiang, Liu, Liu, Shi, & Xu, 2022). Tao et al. (2022) stresses on this approach, how environmental and economic factors are interrelated. However, Green Finance is often analyzed along with economic growth. Economic growth serves as a crucial indicator of a nation's prosperity predominately assessed through the GDP. As nations generate a greater volume of goods and services their economies undergo expansion, signifying heightened activities related to economy and potential for advancement Haseeb, Kot, Hussain, and Jermsittiparsert (2019). Nevertheless, this growth often arises at the cost of the environment. Numerous scholars including Lan et al. (2012) debated how economic factors lead towards ecological deterioration. They argue that as

nations moves towards growth, so do the pressure on natural resources and environmental quality, requiring careful oversight to alleviate adverse effects. Using the data drawn from China Statistical Year Book and EPS database, (Han, Zheng, Xie, Muhammad, & Isik, 2023) analyzed the influence of sustainable financing on economic performance in 30 regions of China spanning 2011 to 2021.

Implementing a baseline regression analysis, the authors find that sustainable financing is positively associated with performance of the economy. By incorporating a sample of 82 countries over the duration 2014 to 2022, the fixed effect is utilized to examine the nexus among environmentally friendly bonds and economic growth. Outcomes reveal that environmentally friendly bonds positively and significantly influence the growth of the economy. (Bajra & Wagner, 2024). Ouyang, Guan, and Yu (2023) used China's provincial panel data for time span of 2014-2018 to determine how green financial indicators contributes to economic growth. Difference in Difference technique is used and empirical findings are documented that green finance policy aids in maximizing quality of economic growth. Secondly, green finance policy assist in advancement of industrial structure.

Similarly, (H. Huang et al., 2023) examined the causation among economic growth and green finance. A simultaneous equation approach is employed to discover the interconnection between investment in green financial instruments and economic growth from 2003-2017 in China's 30 provinces. They concluded that green financial instruments significantly foster economic growth (Wan & Sheng, 2022). Liu and Li (2024) study investigated in China the correlation among green finance, GDP growth, urbanization and usage of the energy by incorporating the quantile ARDL model during the period of 1999 to 2022. Statistical findings advocate green finance adversely impacts economic growth. For 30 provinces of China, Ye, Cai, Wang, and Wang (2023) employed the panel VAR model for the period 2005 to 2020 to explore the causation among development in green financial indicators, CO_2 emissions and economic development.

Empirical results advocate that development in green financial indicators contributes towards development of the economy by reducing carbon emissions. In another study, Zhou, Tang, and Zhang (2020) investigated the effect of sustainable financing on growth of the GDP across 30 provincial regions of China from 2010

to 2017 by incorporating GLS regression analysis. Results reveal that developing green finance will contribute to economic development. By using a methodology of Autoregressive distributed lag and Granger causality, (M. A. Nawaz, Hussain, & Hussain, 2021) examined how green financing development affected Pakistan's GDP growth from 1981 to 2019, and the findings indicate that development in green financing plays a crucial role in boosting Pakistan's GDP growth. T. Zhang and Zhao (2024) analyzed the spatial effects in China among climate financing and GDP from 2001 to 2017 by incorporating a spatial simultaneous equation. The empirical evidence suggest that climate financing is positively correlated with economic development. Liu and Li (2024) considered the region of China, Beijing Tianjin Hebei (BTH) over the period 2010 to 2020 to investigate the interconnectedness among sustainable financing and economic progress. The outcomes of the fixed effect model reveal that sustainable financing has significant and positive influence on each other. Using data collected from 2010 to 2019, (Gao et al., 2022) particularly examine that how green finance is correlated with economic growth. This study utilized spatial econometric methodology on 30 provinces of China. Based on his findings, green finance serves as a key driver in maximizing the real per capita income and aids in reducing harmful impact of pollution. Fan and Zhang (2024) utilized the data from 2011 to 2020 by incorporating double difference technique to analyze effects of sustainable financing on the growth of the economy in China. Empirical evidence illustrates that sustainable finance strengthens the growth of the economy. Moreover, policies related to sustainable financing influence the performance of the economy through technological innovations. Yang, Su, and Yao (2021) study incorporated the GMM to study the nexus between green financial indicators and economic performance. Data from the time interval 2007 to 2019 of 30 provincial regions of China were used for estimation. Therefore, the statistical outcomes reveal that green financing contributes to fostering the economy. Over the timeframe 2013 to 2023, (A. Nawaz, Li, & Su, 2024) considered BRICS to study the effect of different green financing instruments i.e. green loans, green investments and green security on the development of the economy. It was analyzed that green financing instruments serves a crucial determinant in the development of the economy.

TABLE 2.1: GF and EG

Authors	Country	Periods	Econometric Techniques	Findings
Ngo, Doan, Vo, Tran, and Nguyen (2021)	Vietnam	1986 to 2019	Autoregressive Distributed Lag (ARDL)	Green loans & investment in green instruments positively influence GDP.
Nenavath and Mishra (2023)	India	2010 to 2021	Generalized Methods of Moments (GMM)	GF boosts EG.
Ouyang et al. (2023)	China	2014-2018	DID model	GF enhances the quality of economic growth.
L. Huang, Cao, and Zhu (2023)	38 OECD members	2010-2020	Vector Autoregressive model, causality & co-integration approaches	No causal relationship lies among GDP & green bonds.
Wan and Sheng (2022)	China's 30 provinces	2003-2017	Simultaneous equation model	Positive & significant.
Liu and Li (2024)	China	1999 to 2022	Quantile ARDL model	GF exerts negative influence on EG.
Ye et al. (2023)	30 provinces of China	2005 to 2020	PVAR	GFD promotes EG.

Table 2.1: GF and EG (continued)

Authors	Country	Periods	Econometric Techniques	Findings
Zhou et al. (2020)	30 provinces of China	2010-2017	GLS regression analysis	In eastern & western China, GF positively influences EG as a whole.
M. A. Nawaz et al. (2021)	Pakistan	1981 to 2019	Autoregressive distributed lag and Granger causality	GFD has positive impact on GDP growth.
V. Singh and Mishra (2022)	30 countries including middle & high income	COVID-19 pandemic in 2020	OLS regression	Positive.
Nie et al. (2024)	30 provinces of China	2011 to 2019	Difference-in-difference (DID) model	GFRIPZ positively affects EG by supporting the emergence of green innovations.
Gao et al. (2022)	30 provinces of China	2010 to 2019	Spatial econometric methodology	GF promotes EG.
Fan and Zhang (2024)	China	2011 to 2020	Double difference technique	The influence of GF is more pronounced in the Eastern part compared to central & western parts.
Yang et al. (2021)	30 provincial regions of China	2007-2019	Generalized method of moments	GF has positive effect on EG, strengthened by Fintech.

Table 2.1: GF and EG (continued)

Authors	Country	Periods	Econometric Techniques	Findings
A. Nawaz et al. (2024)	BRICS economies	2013 to 2023	Generalized method of moments, Fixed effect method	GF enhances EG.
T. Zhang and Zhao (2024)	China	2001 to 2017	Spatial simultaneous equation	Positive & significant.
Liu and Li (2024)	Beijing Tianjin Hebei (BTH)	2010 to 2020	Fixed effect model	Positive & significant.
Han et al. (2023)	30 regions of China	2011 to 2021	Baseline regression analysis	Positive.
Bajra and Wagner (2024)	82 countries	2014 to 2022	Fixed effect	Positive & significant.

2.2 Impact of Green Finance on Renewable Energy

Scholars have investigated various areas that reduce CO_2 emissions, with renewable energy sources being one of them. Green finance provides funding to renewable energy resources and green financing instruments support investments in clean energy.

Bilal and Shaheen (2023) investigated the interconnectedness among green financial indicators and consumption of renewables. The study takes into account 66 nations from 2004 to 2019. The research work is based upon the framework of the GMM. The findings reveal that environmentally friendly investments accelerate the deployment of resources of renewable energy by maximizing the amount of renewable energy in the fuel supply. Similar findings were made by, Tang and Zhou (2023) who discovered that the role played by green financing in the development of clean energy during the period of 2010 to 2020 by using the Spatial Panel Dobbin Model SPDM. Results indicate that green financing functions as crucial driver in the development of clean energy within local and adjacent areas.

Cheng, Kai, and Zhu (2023) study used a difference in difference (DID) approach to investigate interconnectedness between green financial policies on utilization of renewable energy. Data over the period 2013-2020 of listed enterprises in China was used for estimation.

Hence, results reveal that green financial policies have beneficial implications on the utilization of renewable energy and policies like GFRIPZP maximize energy consumption efficiency by alleviating firms' financing limitations and upgrading their digitalization.

Rasoulinezhad and Taghizadeh-Hesary (2022) consider the top ten Green Leaders to explore the significance of green financing in enhancing energy productivity and development in clean energy. Annual data for 2002-2018 were used, and the theoretical approach, (STIRPAT) was applied. The outcomes reveal that green bonds contributes significantly in facilitating environmentally friendly projects. Ali, Seraj, Türüç, Tursoy, and Raza (2023) used methodology common correlated

effects pooled (CCEP) methodology, over the timeframe 2007–2020 to examine the influence of green financing on clean energy in the short term and long term. Research findings documented that green finance substantially increases the production of clean energy. Subramaniam and Loganathan (2024) examined the effect of environmentally friendly investments on green energy in Singapore for the time span of 2000-2020. The outcomes reveal that environmentally friendly investments in Singapore assist in renewable energy development. Moreover, prices of oil, CO_2 emissions, and consumption of energy are positively related to renewable energy development. The research study of G. Wang et al. (2022) seeks to examine how green financial indicators influence the transformation of energy systems in E7 settings. DEA estimation technique is employed. Outcomes reveal that reliance on clean energy makes a substantial contribution in the transformation of energy systems within E7 context.

Green financing supports developments in green energy through financial assistance and indirectly promotes it through research and development Lee, Wang, and Chang (2023). (C. Li & Umair, 2023) investigated the impact of environmentally friendly investments on clean energy development using a panel co-integration test from 2005 to 2020 across 30 provinces in China. The results indicated that environmentally friendly investments contribute to the growth of clean energy.

Similarly, another study by (Mngumi, Shaorong, Shair, & Waqas, 2022), explored the interconnectedness between green financing and investments in renewables. Using the data from 2005-2019, through applying panel quantile regression methodology. Results advocate that green financing exerts influence on investments in renewables in the short term among BRICS economies. According to Zheng, Du, and Wang (2022), green financing and development in renewable energy have bidirectional causation among each other from the period 2005 to 2018 in China by employing the panel co integration test. However, it is analyzed that green finance does not significantly promote RE in shorter periods, but influence in longer duration.

For China, Feng, Xiao, Zhou, and Ni (2023) study used nonlinear autoregressive distributed lag NARDL and VECM test to assess the impact of sustainable bonds on investment in renewable energy from 1980 to 2020. Empirical findings reveal

that the growth of sustainable bonds is found to be a significant driver of increased investments in renewables while simultaneously mitigating environmental pollution. (Dong, Li, Gao, & Sun, 2023) study used quarterly data from 2016-2021 to analyze the effect of trade and issuance of green financial instruments on the usage of renewable energy. It is analyzed in 6 Southeast Asian countries, green bonds proved to be a productive financing instrument in the deployment of renewable energy.

Taghizadeh–Hesary, Phoumin, and Rasoulinezhad (2023) investigated the effect of green bonds on three types of clean energy resources in Japan over the period 1990-2020 by making the use of Autoregressive distributed lag (ARDL) methodology. Results demonstrate that issuance of green bond has a more pronounced impact on solar and hydro energy than wind energy. Du et al. (2023) study used 30 Chinese provinces to assess the relationship between green financial development and clean energy through applying GMM. Using data for the timeframe 2001-2019, it was found that GFD contributes to China's energy sector through accelerating the maximization pertaining to the proportion of clean energy.

Peng, Shi, Xiao, and Wang (2023) used the spatial simultaneous equation technique and three stage generalized spatial least squares to ascertain the development in green financing and consumption of clean energy during 2008-2019 in 30 provincial regions of China. Findings suggest that GFD and clean energy positively effects each other and have a positive spatial spillover effect. In another study, By incorporating the quantile regression approach (Abbas et al., 2023) over the period 2012-2021 examined how environmentally friendly investments exerts influence on green energy. Outcomes reveal that environmentally friendly investments acts as a key driver in fostering the green energy.

Chen, Umair, and Hu (2024) sought to determine the nexus among green financing and clean energy from 1990 to 2018 by using sample of 30 developing countries. The outcomes of the GMM analysis shows that issuance of green bonds enhances investments in renewable energy. Moreover, banking system plays vital role in the contribution of green financing towards investments in clean energy and the banking sectors that are highly developed have showed positive association among green bonds and clean energy projects.

TABLE 2.2: GF and RE

Authors	Country	Periods	Econometric Techniques	Findings
Bilal and Shaheen (2023)	66 nations	2004 to 2019	Generalized method of moments (GMM)	Indicators of GF are instrumental in promoting the adoption of RE through technological advancements.
Tang and Zhou (2023)	China's 30 provinces	2010-2020	Spatial Panel Dobbin Model, spatial weight matrix method	GF contributes to RED.
Cheng et al. (2023)	China	2003-2020	Difference-in-difference (DID) approach	Green financial policies enhance firms' utilization of RE in the pilot zones & its effect is more pronounced in small firms.
Rasoulinezhad and Taghizadeh-Hesary (2022)	Top 10 green economies	2002-2018	GMM, FMOLS, CCEMG	Green bonds serve as an effective financing instrument for promoting RE projects in long term.
Alharbi et al. (2023)	44 countries	2007 to 2020	Common Correlated Effects Pooled (CCEP)	GF fosters clean energy in long & short run.

Table 2.2: GF and RE (continued)

Authors	Country	Periods	Econometric Techniques	Findings
Subramaniam and Loganathan (2024)	Singapore	2000-2020	DOLS	GF contributes positively to adoption of RE.
G. Wang et al. (2022)	E7 economies	2002-2018	Data Envelopment Analysis (DEA)	GF investment in RE sector for energy transition varies by country e.g. 5% in China, 17% in India, 18.6% in Turkey.
Lee et al. (2023)	China	2001-2019	Ordinary Least Square (OLS)	GF directly enhances green energy, and indirectly fosters it by stimulating R&D activities.
C. Li and Umair (2023)	China	2005-2020	Panel co-integration test	GF exerts positive influence on RED.
Mngumi et al. (2022)	BRICS economies	2005-2019	Panel Quantile Regression, Cross-sectional tests	GF contributes to investments in RE, reducing CO_2 emissions.

Table 2.2: GF and RE (continued)

Authors	Country	Periods	Econometric Techniques	Findings
Zheng et al. (2022)	China	2005-2018	Panel co-integration test, pooled mean group estimators	Long run bidirectional causality exists among GF and RE in eastern & central provinces.
Feng et al. (2023)	China	1980 to 2020	NARDL and VECM Granger causality test	GF and REI have long run causality in the long term.
Dong et al. (2023)	6 Southeast Asian countries	2016-2021	FMOLS and DOLS	Issuance of green bonds supports RE initiatives.
Taghizadeh–Hesary et al. (2023)	Japan	1990-2020	ARDL	Issuance of green bonds impacts solar & hydro more than other energy types.
Du, Shen, Song, and Vardanyan (2023)	30 Chinese provinces	2001 to 2019	Generalized Method of Moments (GMM)	GFD significantly influences the transition towards RE.

2.3 Impact of Renewable Energy on Economic Growth

Energy is widely recognized as fundamental driver behind the progress of industries and overall growth of the economy (Usman, Rasheed, Mahmood, Riaz, & Bashir, 2023). Renewable energy fosters economic growth by minimizing energy costs, enhancing energy security and regional economic development, specifically in rural areas where renewable sources are in abundance.

Many past studies investigated the nexus among the growth of the economy and renewable energy but studies regarding these variables are still limited. Based on empirical analysis, four testable hypotheses have been formulated in relation to renewable energy growth nexus i.e., feedback, growth, neutrality and conservation hypothesis. All of these hypotheses have been validated by empirical analysis by incorporating varying samples.

Hieu and Mai (2022) employed the methods of movement quantile regression (MMQR) estimation for the period of 1990-2020 across 80 developing nations to determine the effect of renewable energy on economic growth. Research findings advocate that renewable energy is positively correlated with the economic growth.

The 1% upsurge in the utilization of renewable energy leads to a boost in Egypt's economy by 1.02% in the longer period and 0.54% in shorter period (Raihan et al., 2025). In addition, Qudrat-Ullah and Nevo (2021) examined how clean energy affects economic development in 37 African nations spanning 2008 to 2014. Findings indicate that the adoption of clean energy enhances economic development in Africa. Hoa, Xuan, Thu, and Huong (2024) utilized 60 economies between 1990 and 2022 to examine the interconnectedness among green energy and economic growth. Applying the Granger causality tests revealed that a two way causality exists among green energy and economic growth. Moreover, the findings suggest that green energy mediates between economic growth and innovation. A study by G. Wang et al. (2022) from 1990 to 2020 in 10 Asian nations to explore how the integration of clean energy effect the growth of the economy. Their research outcomes demonstrated that the deployment of clean energy sources positively and significantly influences the levels of economic growth.

(Xu, Tan, & Zhao, 2025) during the period 1990-2023 seeks to understand the contribution of green energy sources on the GDP growth in Germany. Empirical evidence suggests that clean energy contributes positively to the growth of the GDP. Moreover, it is highlighted that the use of clean energy greatly strengthens the path towards a sustainable economy.

Thach (2025) uses OECD countries to investigate the influence of clean energy and traditional forms of energy on the growth of the economy. Annual data comprising 1965 to 2019 was utilized and Bayesian approach was used for estimation. Hence, results reveal that clean energy and traditional forms of energy positively influences on the growth of the economy, while the contribution of clean energy is more pronounced.

In the context of the Asia Pacific Economic Cooperation (APEC), (Zafar, Shahbaz, Hou, & Sinha, 2019) studied the correlation among renewable energy and per capita income over the duration 1990-2015. Cross sectional dependence was applied and empirical findings suggests that green energy is positively correlated with per capita income.

Saidi and Omri (2020) aimed to investigate the linkages among green energy and economic development during the time period of 1990 to 2014 by employing FMOLS and VECM techniques in context of 15 renewable energy consuming economies. Empirical findings are documented that renewable energy results in promoting the growth of the economy and bi directional causality exists among both variables.

Saad and Taleb (2018) study used 12 European Union countries by applying PVECM test over the time frame 1990-2014 to investigate the interconnectedness among consumption of fossil fuel energy and growth of economy. The research analyzes that unidirectional causality run from growth of the economy to consumption of fossil fuels in short run, whereas a feedback hypothesis is validated among both variables.

Anser et al. (2021) explored that wind power, geothermal and biomass has favorable and substantial impact on economic development of 8 Asian economies but hydro power and solar power has positive and insignificant impact on these

nations from 1990 to 2018 through applying panel vector error correction model (PVECM).

Some studies also reported a negative association among these two variables i.e. renewable energy(RE) and economic growth(EG). (Muazu, Yu, & Liu, 2023) study used 54 African economies by incorporating a panel threshold regression model from 1990 to 2018 to determine how the adoption of renewable energy effect on the growth of economy. Statistical outcomes revealed that the adoption of renewable energy negatively influences the economic progress of African nations. Moreover, it is analyzed that nonlinear association exists among both variables.

In the context of 6 Gulf Cooperation Council (GCC) countries, (Lahrech, Abu-Hijleh, & Aldabbas, 2024) over the period 2001 to 2019 employed the panel regression estimation technique to study the nexus between global green energy and GDP. Findings suggest that green energy have significant and negative impact on GDP growth.

According to M. R. Rahman, Rahman, and Akter (2023) usage of renewable energy negatively contributes to the economy of Bangladesh, in Sri Lanka favorable nexus exists among both variables while in the short run, India exhibits a statistically robust and directionally positive influence on these two variables.

However, in Pakistan, both variables have an inverse relationship during the period 1990 to 2019, in South Asian countries (Pakistan, India, Bangladesh and SriLanka).

Maji, Sulaiman, and Abdul-Rahim (2019) employed dynamic ordinary least squares (DOLS) in fifteen West African nations over the period 1995 to 2014 to analyze the linkage between green energy and economic progress. Results advocate that usage of green energy has adverse effect on the economy. Rehman, Ma, Ozturk, and Radulescu (2022) sought to determine the correlation between non fossil fuel energy, fossil fuel, carbon emissions and GDP growth in Pakistan from 1975 to 2019. By incorporating the linear autoregressive distributed lag methodology, it was found that fossil fuel energy, nonfossil fuel energy and carbon emissions has a significant connection with economic growth of Pakistan in short run while in long term all these variables are beneficial for Pakistan's economy.

(Rusiadi, Hidayat, Rangkuty, Ferine, & Saputra, 2024) during the period 2000 to 2021 in ASEAN region investigated the interplay among clean energy and growth of the economy.

By incorporating static panel regression, it is analyzed that clean energy has a pronounced effect on economy's growth of ASEAN.

Syzdykova, Abubakirova, Erdal, Saparova, and Zhetibayev (2020) documented that 1% rise in the proportion of green energy leads to 0.08% rise in GDP per capita among 8 developing countries. In contrast, 1% rise in the proportion of conventional energy maximizes the GDP per capita by 0.3%.

In addition, (M. M. Rahman & Velayutham, 2020) investigated how clean energy contributes to development of the economy. As per empirical findings clean energy have substantial effects on the economy of 5 South Asian economies.

In line with previous studies, For 26 European countries, Asiedu, Hassan, and Bein (2021) explored the RE-EG nexus for 1990-2018. Panel co integration test indicate that long run association exists between renewable energy consumption (REC) and real GDP per capita.

Alabi, Ackah, and Lartey (2017) study utilized African OPEC member economies (Angola, Algeria and Nigeria) over the period 1971 to 2011 to assess the relationship between renewable energy investments (REI) and economic growth for the shorter and longer term. Statistical outcomes reveal that two way causality exists among renewable energy investment (REI) and economic growth.

With regard to South Caucasus states, Dilanchiev, Umair, and Haroon (2024) examined the interconnection among clean energy and GDP growth by utilizing VAR and causalities test from 1990 to 2021. Results indicate that bi directional causality exists between the growth-energy nexus.

Focusing on Vietnam, (Minh & Van, 2022) utilized autoregressive distributed lag and Granger causality between 1995 and 2019 to consider whether utilization of green energy fosters real GDP. Findings reveal that utilization of green energy is positively interconnected with real GDP in the long run.

TABLE 2.3: RE and EG

Authors	Country	Periods	Econometric Techniques	Findings
Hieu and Mai (2022)	80 developing countries	1990-2020	Movement quantile regression (MMQR)	Growth hypothesis
Raihan et al. (2025)	Egypt	1990 to 2021	Autoregressive distributed lag (ARDL), FMOLS and DOLS	RE boosts EG.
Qudrat-Ullah and Nevo (2021)	37 African countries	2008-2014	Generalized Method of Moments (GMM)	1% increase in RE leads to 0.07% rise in EG short run & 1.9% in long run.
Hoa et al. (2024)	60 economies	1990 to 2022	Granger causality tests	Feedback hypothesis
G. Wang et al. (2022)	10 Asian nations	1990 to 2020	AMG and CCEMG	RE positively & significantly influences EG.
Xu et al. (2025)	Germany	1990-2023	ARDL	RE exerts positive influence on EG, where a 1 % rise in R&D enhances GDP.
Thach (2025)	37 OECD economies	1965 to 2019	Bayesian approach	RE has positive impact on EG.
Zafar et al. (2019)	APEC economies	1990-2015	Cross sectional dependence, Westerlund co-integration test	Bidirectional causality & positive relation exists among RE and EG.

Table 2.3: RE and EG (continued)

Authors	Country	Periods	Econometric Techniques	Findings
Saidi and Omri (2020)	15 major RE consuming economies	1990-2014	FMOLS & VECM techniques	Feedback hypothesis
Anser et al. (2021)	8 Asian economies	1990 to 2018	Panel Vector Error Correction Model (PVECM)	Positive & significant
Muazu et al. (2023)	54 Asian economies	1990 to 2018	Panel threshold regression model	Negative relationship between REC and EG.
Lahrech et al. (2024)	6 GCC countries	2001 to 2019	Panel regression estimation	RE negatively influences GDP.
M. R. Rahman et al. (2023)	South Asian countries	1990 to 2019	Autoregressive distributed lag (ARDL), Toda Yamamoto causality	Positive association lies in long run while negative in short run
Maji et al. (2019)	15 West African economies	1995 to 2014	DOLS	REC is inversely associated with EG.
Rehman et al. (2022)	Pakistan	1975 to 2019	ARDL	Increase in REC increases GDP per capita.

Table 2.3: RE and EG (continued)

Authors	Country	Periods	Econometric Techniques	Findings
Rusiadi et al. (2024)	ASEAN region	2000 to 2021	Static panel regression	Results shows positive association among RE & EG.
M. M. Rahman and Velayutham (2020)	5 South Asian economies	1990 to 2014	FMOLS and DOLS	Unidirectional causality & 1% increase in RE leads to 0.58% rise in EG.
Asiedu et al. (2021)	26 European countries	1990-2018	Panel co integration test and Granger causality test	Bidirectional causality
Can and Korkmaz (2019)	Bulgaria	1990-2016	Toda Yamamoto and Auto Distributed Lag (ARDL)	REC act as a key determinant of EG.
Dilanchiev et al. (2024)	South Caucasus Countries	1990 to 2021	VAR and causalities test	Two way causality exists between RE and EG
Minh and Van (2022)	Vietnam	1995- 2019	ARDL & Granger causality	Positive & unidirectional

2.4 Mediating Role of Renewable Energy Between Green Finance and Economic Growth

Green finance aids the development of renewable energy which promotes economic growth. Countries that opt green financial policies and renewable energy investments experience higher economic growth.

Wu (2023) intends to explore the relationship between green finance, renewable investments and economic performance in OECD countries spanning 2001 to 2019 by employing Generalized Methods of Moments (GMM). Results reveal that renewable energy investment (REI) and green finance have a significant positive relationship with economic performance. In another study, (Netcu, 2023) study used a panel data approach in 27 EU countries spanning 2000 to 2020. The outcome shows that there is an insignificant negative nexus between green finance and economic growth and a positive relationship between green finance(GF) and renewable energy(RE).

M. Li, Hamawandy, Wahid, Rjoub, and Bao (2021) estimated the causal association among green energy, green finance and economic growth with private participation. This study used the wavelet spectrum technique for analysis and findings indicate that a one way causality exists between economic growth and green energy and between green energy and green finance. C. Li and Umair (2023) conducted empirical research to determine the nexus between economic development, growth of RE and green finance in Asian nations. Quantile-on-quantile regression approach was used over the time span of 1995-2018, causality tests suggest that economic development, renewable energy and green finance contribute to environmental footprint. Moreover, they contribute to lessening unemployment and fostering sustainable production.

Over the period 2000-2020, the wavelet power spectrum is used in China to determine the causal relationship between investment in clean energy and green finance while taking into consideration other components including economic growth and output of the renewable energy sector (REO). It is analyzed that a unidirectional causality lies amongst economic growth, investment in renewables and green financing (Bei & Wang, 2023). Tiawon and Miar (2023) used Indonesia to assess the

nexus between renewable energy, environmentally friendly investments and GDP growth. Time series data through 1990-2019 and the Autoregressive Distributed Lag Method (ARDL) was used. Statistical findings suggest that environmentally friendly investments and renewable energy contribute to GDP growth and narrow down carbon emissions.

D. Zhang, Mohsin, and Taghizadeh-Hesary (2022) extend the analysis to Chinese provinces to analyze the liaison among fossil fuel energy, green financing and economic development during 1995 to 2020 by using Generalized Method of Moments (GMM). Findings reveal that fossil fuel energy, economic development and green financing have a one-way causal relationship. A study conducted over the period 1990 to 2020 in ten developed economies using common correlated effects mean group (CCEG) and augmented mean group (AMG) found a positive association among green finance, renewable energy and economic growth Sampene, Li, and Wiredu (2024).

Dai and Xiong (2023) used NARDL and multiple linear regression algorithms to study the nexus among green finance, economic growth and renewable energy over the period 1986 to 2018 in Asian nations. Statistical outcomes suggest that green finance development (GFD) encourages economic growth and renewable energy transformation promotes economic growth. Huang et al. (2023) study sought to determine the association among sustainable financing, clean energy and economic development by employing the dataset of China. Over the period 2000-2020, Bootstrap Autoregressive Distributed Lag (BARDL) advocates that long term association exists between sustainable financing, clean energy and economic development. Moreover, sustainable financing and clean energy mitigate the effect of carbon emissions.

G. Sun, Li, Dilanchiev, and Kazimova (2023) by incorporating NARDL approach from 2000 to 2018 analyzed the contribution of climate financing and green energy towards transforming energy structure. It is analyzed that these factors lead to higher growth rate in the economy of China. From 1990-2022 by incorporating the Gregory Hansen technique, it was analyzed that investing in sustainable financial instruments maximizes the usage of clean energy which in turn contributes to maximization of the progress of the economy in China X. Sun and Waqas (2024).

Table 2.4: Mediating Role of RE

Authors	Country	Periods	Econometric Techniques	Findings
				Significant
Wu (2023)	OECD countries	2001 to 2019	Generalized Methods of Moments (GMM), Fixed Effect Model (FEM)	Positive
Netcu (2023)	27 EU countries	2000-2020	Panel data approach, Method of moments quantile regression	Insignificant negative
M. Li et al. (2021)	China	1990-2020	Wavelet spectrum technique	Unidirectional causality exists among EG,RE and GF,RE
Bei and Wang (2023)	China	2000-2020	Wavelet power spectrum	One way Causality
Tiawon and Miar (2023)	Indonesia	1990-2019	Autoregressive Distributed Lag Method (ARDL)	GF, production of RE contributes to EG.
D. Zhang et al. (2022)	Chinese provinces	1995 to 2020	Generalized method of moments (GMM)	Unidirectional causality lies between variables & EG serves as a mediator.

Table 2.4: Mediating Role of RE (continued)

Authors	Country	Periods	Econometric Techniques	Findings
Sampene, Li, and Wiredu (2024)	Ten developed economies	1990 to 2020	CCEG and AMG	Positive
Dai and Xiong (2023)	Asian nations	1986 to 2018	NARDL and multiple linear regression algorithms	GFD and RE transition encourages EG
H. Huang et al. (2023)	China	2000-2020	Bootstrap Autoregressive Distributed Lag (BARDL)	Bidirectional causality exists among GF, RE and EG.
G. Sun et al. (2023)	China	2000 to 2018	NARDL	GF, RE fosters EG
X. Sun and Waqas (2024)	China	1990-2022	Gregory Hansen	RE, GF is considered to be key drivers in HQED.
Owusu and Acheampong (2025)	E7 economies	1990 to 2020	Driscoll Kraay approach	GF,RE promotes EG

2.5 Moderating Role of Green Technology Between Green Finance and Renewable Energy

Green technology refers to use of science and technology to develop ecofriendly products that protect our environment. Green technology can promote the environmental benefits of renewable energy investments. (C. Li & Umair, 2023) used Chinese listed companies to explore the relationship among green finance development and green technological innovation by employing Poisson and negative binomial distributions over the period 2008-2018. Results suggests that green finance positively enhance green technological innovation.

Jiakui, Abbas, Najam, Liu, and Abbas (2022) undertook the investigation during the period 2011 to 2021 into the interconnection between eco friendly technology, sustainable finance and total factor productivity. They employed non-parametric data development analysis and directional distance function it is analyzed that green technology innovation intensifies the overall productivity. Moreover, green finance contributes positively to green total factor productivity and green financial policies fosters the evolution of green financial markets.

Zheng, Feng, and Chang (2023) utilize 64 countries worldwide by applying the panel Tobit model spanning 2014-2019 to ascertain the impact of green finance on renewable energy innovation(REI). It is analyzed that green finance positively influences renewable energy innovation while green finance promotes innovation more in wind energy and less in other types of renewable energies.

Xiong and Dai (2023) used the time period 1990 to 2020 to investigate the role green financial instruments and sustainable development with interaction term of technological advancement and renewable energy in China. The results indicate renewable energy and technological advancements result in enhancing the effects of green finance. Furthermore, it is observed that environmentally friendly instruments lessen the effects of pollution by stimulating the advancement in green technologies.

Lu, Wu, and Liu (2022) explored 3236 A-share listed companies from China during 2011-2018 by using difference in difference DID technique and different robustness

test such as parallel trend test and placebo test to determine the effect of green finance reform and innovations on green technology. Findings indicate that green finance reform can boost technological innovation among enterprises and GFRI enhances innovation in green technology by mitigating the internal and external financial challenges. Moreover, the effect of green technology is more pronounced in the eastern regions of China than the western regions of China.

Pang, Zhu, and Yu (2022) study used different market sizes and conditions in short and medium term to determine the impact of green finance on green technology and carbon emissions over the period Jan 1,2016 to April 22,2022. Wavelet based quantile on quantile methodology was used for this purpose in China. In long run positive effects are found out in bull green finance market and negative effects appear in bear green finance markets.

The moderating and indirect effect of sustainable finance and eco innovation is investigated in the Yangtze River Economic Belt's Industrial Structure during the period 2005-2019. Using 11 provinces of the Yangtze River Economic Belt and the entropy method, it is analyzed that innovation in ecofriendly technology performs a pivotal intervening function in upgrading industrial structure via sustainable finance. The interaction effect of ecofriendly technology accounts for the influence of green financial instruments on the transformation of industrial structure. (T. Zhang & Zhao, 2024).

Jiang et al. (2022) study used micro level and provincial level panel dataset of Shanghai and Shenzhen A share listed company from time period 2012 to 2019. Mediating and moderating effects were applied to ascertain the impact of environmentally friendly investments on green technological innovation by employing panel econometric data. Results advocate that environmentally friendly investments boost green innovation by relieving financing constraints.

Fan and Zhang (2024) investigated the how green finance exerts influence on clean technologies and the moderating role of green finance on clean technologies from 2010 to 2017 in China. Through the spatial Durbin model, it is analyzed that green finance fosters innovation in clean technologies across different regions of China. Moreover, in terms of spillover effects green finance efficiently promotes green technology innovation.

Yin, Chen, and Ji (2023) study used 30 provinces of China to examine the interaction effect of green financial indicators on eco innovation by using bi-directional fixed model. Using the panel data from 2002-2019, results reveal that green financial indicators strengthens green technology innovation.

For A share listed firms situated in Shanghai and Shenzhen, Zeng, Tong, and Yang (2023) used a difference in difference DID approach to assess the how green financial policies exerts influence on green invention patents of enterprises for the time period of 2012 to 2020. Empirical findings suggest that (GRIFPZ) upgrade green invention patents of enterprises. Moreover, for large scale enterprises, public, non-polluting companies have beneficial impact on the implementation of green invention patents.

D. Zhang et al. (2022) investigated the nexus among green financial instruments, green energy, innovation in technology and CO_2 emissions by incorporating the control variables i.e., foreign direct investment, research and development and GDP per capita in G-20 countries. During 2008 to 2018, fixed effect, quantile regression and OLS regression model advocate that green financial instruments, green energy and innovation in technology reduces CO_2 emissions.

Using the data drawn from S&P benchmark for Green Bond Green Bond Index and S&P Clean Energy Index, (Madaleno, Dogan, & Taskin, 2022) investigated the causal relationship among green financial initiatives, green energy and environmentally friendly technologies from July 31, 2014 to Oct 12, 2021, through applying the Granger causality technique in China. Findings suggest that bidirectional causality exists between green energy, green financial initiatives and environmentally friendly technologies.

In the context of developing economies, (Sethi, Behera, & Sethi, 2023) employed the technique of Driscoll Kraay and SGMM from 1998 to 2019 to investigate the role played by green financing, utilization of green energy resources and environmentally friendly technology in contributing towards achieving environmental sustainability by abating carbon emissions. However, the moderating role played by environmentally friendly technology with green financing negatively influences CO_2 emissions.

TABLE 2.5: Moderating Role of GT

Authors	Country	Periods	Econometric Techniques	Findings
Lin and Bai (2023)	China	2008-2018	Poisson and negative binomial distributions, panel threshold model	GF positively influences GT
Zheng et al. (2023)	64 countries	2014-2019	Dynamic panel model, panel Tobit model	GF exerts positive influence on RET
Xiong and Dai (2023)	China	1990 to 2020	GMM technique	RE and technological innovations boosts green financial activities.
Lu et al. (2022)	China	2011-2018	DID, Parallel trend test and Placebo inspection	GFRI play a crucial role in in promoting GT innovation at enterprise level.
Pang et al. (2022)	China	Jan 1, 2016 to April 22, 2022	Wavelet based quantile on quantile, QQR approach	Positive effects appeared in bull market while negative effects appeared in bear market.
T. Zhang and Zhao (2024)	11 provinces of Yangtze River Economic Belt	2005-2019	Entropy method	GT innovation serve as a mediating mechanism in promoting industrial structures through GF.
Jiang et al. (2022)	Shanghai and Shenzhen	2012 to 2019	Panel econometric data	GFD promotes GT innovation at enterprise level.

Table 2.5: Moderating Role of GT (continued)

Authors	Country	Periods	Econometric Techniques	Findings
Fang and Shao (2022)	China	2010-2017	Spatial Durbin model	GF fosters GT
Yin et al. (2023)	30 provinces of China	2002-2019	Bi-directional fixed effect model	Positive moderating effect
Zeng et al. (2023)	Shanghai and Shenzhen	2012 to 2020	difference-in-difference DID model	GTFP upgrade GT
Madaleno et al. (2022)	China	July 31, 2014 to Oct 12, 2021	Granger causality technique	Bi-directional causality
Sethi et al. (2023)	Developing economies	1998 to 2019	Driscoll Kraay and SGMM	GT negatively influences CO_2 emissions
Han et al. (2023)	China	1995-2019	STRIPAT approach	Bi- directional & Uni-directional causality

2.6 Moderating Role of Green Technology on The Mediating Effect of Renewable Energy Between Green Finance and Economic Growth

Green technology has significantly reduced the cost of producing clean energies by making it more accessible and competitive. Through advances in manufacturing and streamlined supply chains, sources of renewable have become increasingly economically viable. However, the technological advancements arising from innovations in ecofriendly technologies enhance the reliability, scalability and versatility of clean energy, thereby essentially maximizing its overall utility and economic contribution (Dugan et al., 2024).

A study by (Sampene, Li, & Wiredu, 2024) points out the role played by GF, EG, RE, innovation in technologies and EG on ten economically advanced economies. They advocate that boosting the of the sources of clean energy and expansion of the green financial initiatives directly support the development of the economy. The importance of investing into innovation is highlighted, it not only leads to ecological balance but also fosters growth in the economy.

Guo, Dong, Feng, and Zhang (2023) documented that green financing not only allocates capital towards climate initiatives but also act as a catalyst for technological advancements by promoting environmentally responsible activities within firms. In addition, (Wen, He, Jing, & Haroon, 2025) utilized the GMM approach to analyze how sustainable financing and sources of the green energy effects on the performance of the economy. The authors demonstrate that green financing instruments not only channel capital into sectors of sustainable energy but also maximize investment in green energy in terms of developmental impact and environmental value. The results corroborated that adoption of green energy and financial policies can achieve twofold advantages; drive GDP growth as well as safeguard ecosystems.

In the context of E7 economies, Owusu and Acheampong (2025) studied the interplay among green financing, clean energy and development of the economy.

Driscoll Kraay approach has been used over the duration 1990 to 2020. Findings advocate that green financing and utilization of clean energy have beneficial effects on the development of the economy. Han et al. (2023) incorporated the STRIPAT model to examine the contribution of green financing, clean energy and green innovation in attaining environmental sustainability in China from 1995-2019. Findings indicate that green financing contributes towards abating CO_2 emissions and bi directional and unidirectional relationship exists among variables.

Similarly, In the context of EU states, Xu et al. (2025) quantify the interaction between the environmentally friendly investments and investments in clean energy quantifying the encouragement of economic outcomes. Their findings indicate that green finance not only promotes the mobilization of capital into projects related to clean energy but also improve their economic benefits and ecological benefits, thus enabling a dual strategic effect.

From above mentioned literature it is analyzed that liaison between green finance, renewable energy, green technology and economic growth is not widely discussed in the prior studies. Although the nexus between green financing, renewable energy, clean technology and growth of the economy is studied but their results are inconclusive or mixed, so more investigation is required to study it further.

Findings of these studies with different relationships and methodologies varies from region to region. Despite the extensive literature, debate is not settled due to diverse and mixed findings. Many studies sought to determine the relation among environmentally friendly investments, green energy and growth in the economy (Wen et al., 2025; Xu et al., 2025; Meirun, Mihardjo, Haseeb, Khan, & Jermsittiparsert, 2020). Also some past studies confirmed the nexus among environmentally friendly technology with green finance and clean energy (Behera, Behera, & Sethi, 2024; Zheng et al., 2023) and sustainable financing, innovation in technology, clean energy and development of the economy (Sampene, Nsiah, & Wiredu, 2024) and some of the empirical studies reported bidirectional causality between renewable energy sources and economic growth (Muazu et al., 2023; Qudrat-Ullah & Nevo, 2021) However, (Madaleno et al., 2022) recommended to further study green finance with other determinants

TABLE 2.6: Moderating role of GT and mediating role of RE

Authors	Country	Periods	Econometric Techniques	Findings
Dogan, Nketiah, Ghosh, and Nassani (2024)	BRICS	2000-2022	FMOLS & DOLS	GT positively influenced RED in BRICS.
Sampene, Li, and Wiredu (2024)	10 industrialized nations	1990-2020	CCEG and AMG	GF, GT significantly enhances EG by mitigating the pollution.
Wen et al. (2025)	22 EU members	2000 to 2022	Sys-GMM	GF is vital for accelerating the transition to sustainable energy systems. However, investments in RE contribute significantly to GDP growth.
Xu et al. (2025)	22 EU states	2003-2025	GMM	The findings reveal that environmentally friendly investments in RE enhance the adoption of clean energy. In addition, IRE contribute to EG.
Guo et al. (2023)	30 Chinese provinces	2005-2019	Spatial Durbin Model	GF has spillover effects on RE in domestic and adjacent areas.

2.7 Hypotheses

H1: Green finance has a positive impact on economic growth.

H2: Green finance has a positive impact on renewable energy.

H3: Renewable energy has a positive impact on economic growth.

H4: Renewable energy mediates between green finance and economic growth.

H5: Green technology moderates between green finance and renewable energy.

H6: Green technology moderates the indirect effect of renewable energy in such a way, higher green technology will strengthen the indirect impact of renewable energy on economic growth.

2.8 Theoretical Framework

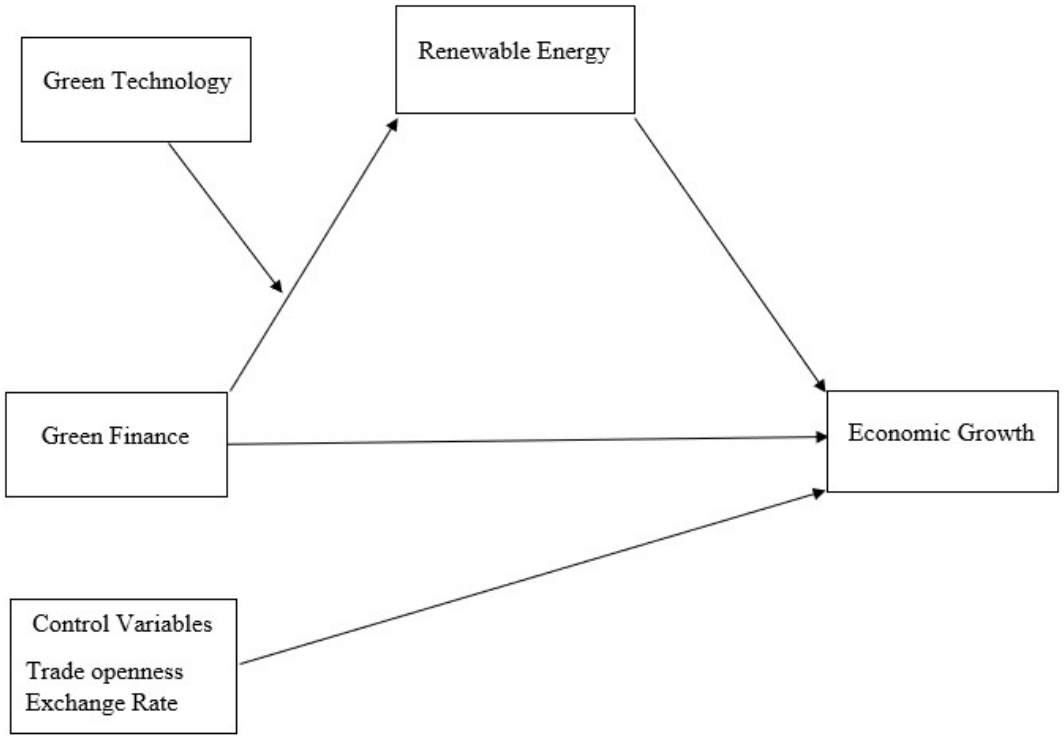

FIGURE 2.1: Research Model

Chapter 3

Research Methodology

3.1 Data

This chapter portrays the process for the extraction of data and the sources through which data was gathered. Data used in the study was retrieved from World Development Indicator (WDI), Our World in data and Organization for Economic Cooperation and Development (OECD). The methodology aims to examine moderated mediation effect that how green technology moderates the indirect effect of green finance on economic growth through renewable energy.

3.2 Population

The population of this study comprises of all the countries globally.

3.3 Sample

The sample includes 80 countries among 266 countries reported in Table 3.1 and these countries are selected on the basis of data availability. Primarily, 161 countries data were collected ranging from 1960-2022 but due to the non-availability of data and missing values, many countries are excluded. Panel data of all these countries is used in the analysis ranging from 2000 to 2021. These years are chosen

in the sample because numerous countries were not reporting regular data prior to 2000.

Table 3.1: List of Countries

Algeria	Central African Republic	Ghana
Argentina	Chile	Guatemala
Armenia	China	Guyana
Azerbaijan	Colombia	Honduras
Bahamas	Costa Rica	India
Belarus	Dominican Republic	Jamaica
Belize	Ecuador	Jordan
Bolivia	Egypt, Arab Rep.	Kazakhstan
Bosnia and Herzegovina	EI Salvador	Kenya
Brazil	Ethiopia	Kyrgyzstan
Burkina Faso	Gabon	Laos
Cameroon	Georgia	Lebanon
Liberia	Morocco	Turkiye
Madagascar	Myanmar	Ukraine
Malaysia	Namibia	Uruguay
Mali	Nepal	Uzbekistan
Mauritius	Sri Lanka	Venezuela, RB
Mexico	Sudan	Viet Nam
Moldova	Thailand	Yemen, Rep
Mongolia	Tunisia	Zimbabwe
Bangladesh	Cote d'Ivoire	Indonesia
Barbados	Cuba	Iran, Islamic Rep.

3.4 Variables Description

In this study green finance is taken as independent variable, economic growth as a dependent variable, green technology as a moderator, renewable energy as a mediator and trade openness and exchange rate as control variables.

3.4.1 Economic Growth (EG)

According to Kuznets (1973) growth in economy is termed as the development of country in providing goods to the people and satisfying all the demands. This improvement relies on technological advancements and variations in institutions and ideas. This study uses Gross Domestic Product (GDP) per capita (constant 2015US$) as a proxy for economic growth. Dam and Sarkodie (2023) and Hwang (2022) used this proxy for economic growth, natural log is of measure is taken. The data source for economic growth is World Development Indicators (WDI).

3.4.2 Renewable Energy (RE)

The International Energy Agency (IEA) defined renewable energy as energy sourced from natural resources that are replenishing rapidly than they are consumed. Solar energy, wind energy, geo thermal, hydro and biomass are the sources of renewable energy through which it can be obtained.

(Rusiadi et al., 2024; Hieu & Mai, 2022) used a renewable energy consumption proxy for renewable energy. RE is measured as a percentage of total energy consumption. Data source for RE is World Development Indicators (WDI).

3.4.3 Green Finance

Green finance, which encompasses financial investments directed towards sustainable development projects and initiatives has emerged as a crucial factor influencing economic and adverse environmental effects.

Chen et al. (2024) used International financial flows to developing countries in support of clean energy R&D and renewable energy production, including the hybrid systems (US$ millions at constant value) to proxy green finance. The data source of green finance is World in Data.

The natural log of "International financial flows to developing countries in support of clean energy and renewable energy production" is used as a measure of green finance.

3.4.4 Green Technology

Green technology also termed as clean technology or eco technology encompasses innovative products and processes aimed at lessening the impact on the environment and fostering sustainable development.

Chen et al. (2024); Han et al. (2023); Tariq et al. (2022), used the Development of environment-related technologies, % all technologies to proxy green technology. It will symbolize as GT in current study. Organization for Economic Cooperation and Development (OECD) is used as a data source for GT.

3.5 Control Variables

3.5.1 Trade Openness

First control variable is Trade openness; it is symbolized as (TO) in whole study. TO refers to Trade (% of GDP) as proxy for trade openness. Trade (% of GDP) is used as a proxy of Trade openness by previous studies.

Prior studies Ali et al. (2023) and Chen et al. (2024) used this proxy to measure trade openness in their studies. Data source for TO be World Development Indicators given by World Bank.

3.5.2 Exchange Rate

Second control variable which is used in the study is exchange rate. Real exchange rate is termed as nominal exchange rate adjusted for inflation differences among the economies.

Moreover, it signifies the actual purchasing power of the currency regarding goods and services (Kıpıcı & Kesriyeli, 1997). Real effective exchange rate index (2010=100) is used as proxy for exchange rate. It will be denoted by ER in the whole study. World Development Indicator (WDI) is used as a data source for ER.

TABLE 3.2: Variables Description

Variable Type	Symbol	Measurement of variables	Data Source	References
Dependent variable				
Economic Growth	EG	GDP per capita	World Bank Database	Dam and Sarkodie (2023)
Independent variable				
Green Finance	GF	International financial flows to developing countries in support of clean energy, R&D &	Our World in Data	Chen et al. (2024)
Mediator		renewable energy production,including the hybrid systems (US$ millions at constant value)		
Renewable Energy	RE	% of total energy consumption	WDI	Rusiadi et al. (2024)
Moderator				
Green Technology	GT	Development of environment related technologies, % all technologies	OECD	Han et al. (2023)
Control Variables				
Trade openness	TO	Trade (% of GDP)	WDI	Ali et al. (2023)
Exchange Rate	ER	Real effective exchange rate index (2010=100)	WDI	Ashour (2023)

3.6 Structural Equation Modeling (SEM)

In 1969, a Swedish statistician named Karl Gustav Joreskog introduced the concept of structural equation modeling. His work laid the foundation for structural equation modeling (SEM), an extensive statistical method used in social science research to analyze complex relationships between variables (Jöreskog, 1969). Structural Equation Modeling is an advanced statistical technique that facilitates the researchers to examine the interconnection among observed and latent constructs. Byrne (2010) states that SEM enumerates the interconnectedness among variables through utilizing the two primary set of equations i.e.; structural equations and measurement equations. Measurement equations evaluates the precision of suggested measurements through analyzing the linkage among latent variables and their corresponding indicators. Testing the statistical hypothesis for the study is facilitated by structural equations which guides about the evaluation of proposed linkages between the latent constructs. In contrast to traditional analysis, SEM permits the incorporation of latent variables in the analysis and is not only confined to associations amongst constructs and observed variables. It efficiently integrates regression analysis and factor analysis.

SEM provides the insights on proposed model through the interplay of various variables. Similar to regression, SEM articulates the effect of intervening variable concerning the connection among outcome and criterion variable. Typically, SEM is frequently chosen by researchers as compared to regression as it accounts for measurement errors, takes into account multiple independent and dependent variables and latent constructs. SEM holds significance for defining the model that needs to be estimated and estimating the goodness of fit and parameter estimates of the proposed model. Structural equation modeling has emerged as a powerful tool in the domains of management and the social sciences (Anderson & Gerbing, 1988). According to Fakhfakh and Jarboui (2020) and Zainudin (2012) SEM can be preferred over other techniques due to its adaptability as it can generate an estimates precisely and accurately during prediction. SEM analysis undergoes through phases of model formulation, collection of data, evaluation of the model, model estimates and modification of the model.

3.7 Econometric Models

In this study, Structural Equation Modeling is used as a statistical technique to determine the nexus between exogenous, endogenous, moderating and mediating variables such as green finance, economic growth, renewable energy and green technology. The subsequent model in which equation estimates how economic growth influences green finance.

$$\mathrm{EG}_{it} = \beta_0 + \beta_1 \mathrm{GF}_{it} + \beta_2 \mathrm{TO}_{it} + \beta_3 \mathrm{ER}_{it} + \varepsilon_{it} \tag{3.1}$$

This is the basic model where EG represents economic growth, while i indicates the country and t indicates the year. GF is measured as a green finance. TO is the trade openness of country i at year t and ER is the exchange rate of country i at year t.

Path a

Path a is constructed to examine the interconnection among exogenous and mediating variable i.e. green finance and renewable energy.

$$\mathrm{RE}_{it} = \beta_0 + \beta_1 \mathrm{GF}_{it} + \beta_2 \mathrm{TO}_{it} + \beta_3 \mathrm{ER}_{it} + \varepsilon_{it} \tag{3.2}$$

If the coefficient of renewable energy is significant, it indicates that GF significantly influences renewable energy, hence fulfilling the first condition of mediation. However, if the results are insignificant it indicates that renewable energy doesn't mediate between green finance and economic growth.

Path b

In path b, the influence of renewable energy on endogenous variable is investigated.

$$\mathrm{EG}_{it} = \beta_0 + \beta_1 \mathrm{RE}_{it} + \beta_2 \mathrm{TO}_{it} + \beta_3 \mathrm{ER}_{it} + \varepsilon_{it} \tag{3.3}$$

Where,

- EG is Economic Growth

- RE is Renewable Energy
- TO is Trade openness
- ER is Exchange Rate
- β_1 is coefficient for Renewable Energy
- β_2 is coefficient for Trade Openness
- β_3 is coefficient for Exchange Rate
- i is cross section
- t is time period
- ε is the error term

If the coefficient of RE is significant, it comprehends that renewable energy has a significant influence on economic growth and renewable energy can be used as a mediating variable.

Path c

Path c is established to investigate the mediating role of renewable energy on economic growth. To analyze the mediating effect, following equation is used:

$$\mathrm{EG}_{it} = \beta_0 + \beta_1 \mathrm{RE}_{it} + \beta_2 \mathrm{GF}_{it} + \beta_3 \mathrm{TO}_{it} + \beta_4 \mathrm{ER}_{it} + \varepsilon_{it} \tag{3.4}$$

If the estimate of RE and GF is significant, it indicates that renewable energy mediates the relationship among economic growth and green finance.

Where,

- EG is Economic Growth
- RE is Renewable Energy
- GF is Green Finance
- TO is Trade openness

- ER is Exchange Rate
- β_1 is coefficient for Renewable Energy
- β_2 is coefficient for Green Finance
- β_1 is coefficient for Trade Openess
- β_1 is coefficient for Exchange Rate
- i is cross section
- t is time period
- ε is the error term

3.8 Moderation Analysis

Following equation illustrates how green technology moderates a path i.e. the relationship between green finance and renewable energy.

$$\mathrm{RE}_{it} = \beta_0 + \beta_1 \mathrm{GF}_{it} + \beta_2 \mathrm{GT}_{it} + \beta_3 (\mathrm{GF} \times \mathrm{GT})_{it} + \beta_4 \mathrm{TO}_{it} + \beta_5 \mathrm{ER}_{it} + \varepsilon_{it} \quad (3.5)$$

Where,

- RE is Renewable Energy
- GF is Green Finance
- GT is Green Technology
- TO is Trade openness
- ER is Exchange Rate
- β_1 is coefficient of Green Finance
- β_2 is coefficient of Green Technology
- β_3 is coefficient of the interaction term between Green Finance and Green Technology

- β_4 is coefficient for Trade openness
- β_5 is the coefficient of Exchange Rate
- i is cross section
- t is time period
- ε is the error term

3.9 Moderated Mediation Analysis

Following equation illustrates how green technology moderates a path i.e. the relationship between green finance and renewable energy.

Following equation represents the moderated mediation impact of green technology in the GF-RE-EG nexus in the developing economies that how green technology moderates the indirect effect of green finance on economic growth via renewable energy.

$$EG_{it} = \beta_0 + \beta_1 GF_{it} + \beta_2 RE_{it} + \beta_3 (GF \times GT)_{it} + \beta_4 TO_{it} + \beta_5 ER_{it} + \beta_6 + \varepsilon_{it} \quad (3.6)$$

Where,

- EG is Economic Growth
- GF is Green Finance
- RE is Renewable Energy
- GT is Green Technology
- TO is Trade openness
- ER is Exchange Rate
- β_1 is coefficient of Green Finance

- β_2 is coefficient Renewable Energy
- β_3 is coefficient of Green Technology
- β_4 is the coefficient of the interaction term between Green Finance and Green Technology
- β_5 is coefficient for Trade openness
- β_6 is the coefficient of Exchange Rate
- i is cross section
- t is time period
- ε is the error term

Chapter 4

Result and Discussion

4.1 Descriptive Statistics

Descriptive statistics demonstrate the fundamental characteristics of the data in the study. Table 4.1 exhibits the mean, standard deviation, maximum and minimum for each variable. The mean reflects the average value, the standard deviation indicates the deviation from the mean and the maximum and minimum values depict the range of the data.

Table 4.1: Descriptive Statistics

	Mean	**Std. Dev**	**Max**	**Min**
EG	11.162666	0.762759	13.164841	9.298178
GF	7.061188	1.335342	9.128897	4.000000
RE	24.382609	19.104203	91.300000	0.100000
GT	14.324962	11.275311	100.000000	1.146132
TO	66.531010	30.920655	220.406789	22.105976
ER	97.042042	19.223298	296.547529	55.585927

EG = Economic Growth, GF = Green Finance, RE = Renewable Energy, GT = Green Technology, TO = Trade Openness, ER = Exchange Rate

Results indicate that EG has a mean value of 11.162666 with a standard deviation of 0.762759. The value of the standard deviation depicts the variation in the data set from the mean value. It indicates that economic growth can increase or decrease by 76.27% from country to country and year to year. The minimum value is 9.298178 and the maximum value is 13.16484. The mean value of GF is 7.061188, with a standard deviation of 1.335342 which shows that the average value of green finance may differ up to 1.335342% from country to country and year to year.

The maximum value of GF is 9.128897 and the minimum value is 4.000000. the mean value of RE is 24.382609 and the standard deviation is 19.104203. The maximum value of RE is 91.30 and the minimum value is 0.100000. The mean value of GT is 14.32 and the standard deviation of 11.27. The minimum value of GT is 1.146132 and the maximum value is 100.000000. TO displays a mean of 66.53 with a standard deviation of 30.92. The maximum value of TO is 220.406 however minimum value is 22.10. Moreover, the average value of ER is 97.04, standard deviation is 19.223. The maximum value of ER is 296.54 while the minimum value in the sample set is 55.58.

4.2 Correlation Analysis

Correlation analysis is an approach employed to assess whether a correlation among two variables exist or not, if so how strong the relationship is. It signifies the degree to which a variation in one variable correlates with a variation in another variable. To ascertain the interconnection among different variables, correlation analysis was performed. Results of the correlation analysis are reported in Table 4.2

The findings indicate that there is a positive association between economic growth, green finance, renewable energy, green technology and exchange rate while trade openness is negatively correlated with economic growth. Green finance is positively correlated with renewable energy, green technology and exchange rate while negatively correlated with trade openness. Renewable energy depicts a positive connection with green technology, trade openness and exchange rate. However,

Table 4.2: Correlation

	EG	**GF**	**RE**	**GT**	**TO**	**ER**
EG	1.000000					
GF	0.2088887	1.000000				
RE	0.105869	0.2472566	1.000000			
GT	0.154465	0.1104647	0.3043983	1.000000		
TO	-0.2356088	-0.1140808	0.07779848	0.0133935	1.000000	
ER	0.1243853	0.01551679	0.08268169	-0.01749655	-0.06704667	1.000000

EG = Economic Growth, GF = Green Finance, RE = Renewable Energy, GT = Green Technology, TO = Trade Openness, ER = Exchange Rate

green technology is positively correlated with trade openness and negatively with exchange rate. Lastly, trade openness is negatively correlated with the exchange rate.

4.3 Unit Root Test

Before going for any analysis in the study it is essential to perform unit root tests to check the stationary of the data. It is indicative of non stationarity when time series constitutes unit root and its values are greatly influenced by time, which leads to forecasting and analysis issues. If presence of unit root is detected, it indicates non-stationarity which needs to be transformed by making it stationary before further analysis.

The table 4.3 provides the results of two-unit root tests, Augmented Dickey Fuller (ADF) and Phillips-Perron (PP) test. Green Finance (GF), Economic Growth (EG), Renewable Energy (RE), Green Technology (GT), Trade openness (TO), Exchange Rate (ER). It shows the results of panel unit root test at level including the statistic and probability of every variable. For each variable, ADF and PP test statistics are negative and corresponding p-values are 0.0236, 0.0014 and 0.0012, which are below the commonly accepted significance level of 0.05. These result suggest that the time series for GF, EG, RE, GT, TO and ER are stationary,

meaning their statistical properties remain stable over time. Therefore, these variables do not require further transformation and are suitable for analysis.

TABLE 4.3: Panel Unit Root Test

Augmented Dickey Fuller Phillips-Perron				
Variables	**Statistic**	**Prob**	**Statistic**	**Prob**
GF	-10.65404	0.000	-29.50189	0.0000
EG	-7.711342	0.000	-8.011938	0.0000
RE	-2.250853	0.0236	-3.547064	0.0004
GT	-3.190343	0.0014	-11.16999	0.0000
TO	-3.507941	0.0005	-3.245024	0.0012
ER	-20.63348	0.0000	-20.17325	0.0000

4.4 Results

To analyze the moderated mediation effects this study conducted regression analysis by incorporating Structural Equation Modeling (SEM) in R studio. Understanding the intricate relations among dependent variable, independent variable, mediator and moderator is made possible by it. The paths demonstrate the nexus among variables in the structural equation model.

The study specifies path a, path b and path c. Path a represents the impact of green finance on renewable energy, path b represents the impact of renewable energy on economic growth and path c represents the impact of green finance on economic growth. The estimate indicates the coefficient of the relationship among the variables specified by the path. It shows how one variable changes with respect to change in other variable. The standard error measures the variability of an estimate. A small standard error indicates more precise estimate. However, z-value is the ratio of the estimate to its standard error. It indicates that how far a number is from standard deviation. The higher z-value represents that estimate diverges from the null hypothesis and is more likely to be statistically significant.it also tells that how far the estimate is from zero.

The results of the SEM are displayed in Table 4.4 comprising of the estimate, standard error, z value and p value.

TABLE 4.4: Direct Effect of X on Y

	Estimate	**Std.Err**	**z-value**	**P(>|z|)**
EGR ∼ (c) GFR	0.223	0.059	3.768	0.000

The above stated results are showing that green finance has a positive and significant impact on economic growth. The estimate for path a is 0.223 and a p-value 0.000 less than a threshold of 0.05. This indicates that increase in green financing activities leads to foster the growth of economy.

TABLE 4.5: Direct Effect of X on M

	Estimate	**Std.Err**	**z-value**	**P(>|z|)**
RER ∼ (a) GFR	0.204	0.055	3.714	0.000

The coefficient of 0.204 indicates that there is positive association among green finance and renewable energy. This means that for every one-unit increase in green financing activities tends to increase 0.204 percent RE by average. The statistical significance of this finding is established by its p-value of 0.000 which falls below the threshold of 0.05 which depicts that second hypothesis of the study is accepted.

TABLE 4.6: Direct Effect of M on Y

	Estimate	**Std.Err**	**z-value**	**P(>|z|)**
EGR ∼ (b) RER	0.317	0.064	4.982	0.000

Then, the third hypothesis of the study that renewable energy has a positive and significant impact on economic growth is also supported, which is reflected by the

coefficient of 0.317 and p-value 0.000 less than 0.05. Positive estimate indicates that 1 percent increase in renewable energy to increase 0.317 unit increase in growth of the economy, holding all other factors constant.

4.5 Mediation Analysis

Mediation is a statistical technique employed to examine the underlying mechanisms or the path through which an independent variable affects a dependent variable. Baron and Kenny (1986) introduced the concept of mediation. They presented the four conditions to estimate mediation. The independent variable must have a significant impact on a mediator, the independent variable must have a significant impact on the dependent variable, the mediator must be associated with the dependent variable while accounting for IV and the influence of IV on DV should be minimized upon the addition of the mediator in the model.

Some of the researchers contradict Baron and Kenny that the indirect effect is not captured through the four steps of Baron and Kenny. In 1982 Sobel introduced an approach to calculate the indirect effect by taking a product of two paths i.e. a and b. In accordance with Fakh and Fakh (2020), previous researchers suggest the use of the Sobel test to validate the significance of mediation and to confirm the validity of estimates of both independent and mediating variables. Both methodologies produce the same results using standard errors while the difference lies in their regression equations. Moreover, mediation analysis is widely used in the domain of social sciences.

To test the indirect effect present study utilized Sobel's test comprising of the estimate, standard error, z value and p-value for the indirect effect is appended below:

Table 4.7: Indirect Effect

	Estimate	**Std.Err**	**z-value**	**P(>—z—)**
indirect	0.065	0.022	2.978	0.003

Results confirm the indirect effect of renewable energy on the relation between green finance and economic growth. The findings indicate the significant of 0.003

which meets the criteria of $p < 0.05$ and positive coefficient of 0.065 depicts that green financing activities lead to maximize renewable energy initiatives which in turn contributes to higher growth in the economy.

4.6 Moderation Analysis

Moderation is an approach that seeks to determine under what circumstances the relation between predictor and criterion variable exists or varies the strength or direction through addition of third variable (Baron & Kenny, 1986). In regression analysis, interaction term is created between moderator and independent variable to study the moderator.

Table 4.4 illustrates the results of regression analysis to investigate the nexus among EG (dependent variable) and GF (Independent variable) with the moderating impact of green technology. This analysis incorporates the interaction term (GF * GT) to assess the moderating effect of Green technology on the relationship between GF and growth in the economy. The coefficient for this interaction term is 0.260 with a standard error of 0.055 and a p-value of 0.000 depicts that this interaction effect is statistically significant. The significant positive coefficient reflects that impact of green financing on growth in economy is stronger in countries that possesses higher levels of green technology. The positive coefficient depicts that the countries who opted green technology, the relationship between green finance and growth in economy is more robust. As green technology advances, the efficiency of green finance in promoting the adoption of renewable energy strengthens. Precisely, green technology maximizes the productivity of financial investments in renewable energy enabling economies and firms to enhance the advantages of green financing.

Table 4.8: Moderation

	Estimate	**Std.Err**	**z-value**	**P($>\|z\|$)**
RER ∼ GFR_GTR	0.260	0.055	4.746	0.000

4.7 Moderated Mediation Analysis

James and Brett (1984) presented the additional requirement of mediation by incorporating a moderator into the with model of the mediation, aiming to reveal the presence of moderated mediation model.

Afterwards, Baron and Kenny (1986) also demonstrated an illustration by integrating moderation and mediation through highlighting the probability of introducing the moderated mediation model. Additionally, Muller et. al (2005) expanded the prior research work by introducing the model equations that govern a moderated mediation mechanism.

Preacher et. al (2007) examined a numerous common types and brought to attention the mathematical equation of moderated mediation impact which is also termed as conditional indirect effect.

The moderated mediation effect of green technology on economic growth by maximizing the mediation role renewable energy was analyzed using Model No 7 of the Process Macro. This model was run using the 1000 bootstrap values and level of confidence was set at 95%.

Index of moderated mediation is developed by Preacher, Rucker and Hayes (2007) and more additions were made by Hayes (2015). It explains up to what extent the indirect effect of an independent variable on a dependent variable through a moderator changes in result of moderator (W).

If the index is different from zero or having same signs either positive or negative, it depicts that the indirect effect is moderated.

In the first stage of moderated mediation model, the moderator W impacts the relationship in Path a i.e. independent variable and mediator.

Table 4.9: Index of moderated mediation

	Index	**BootSE**	**BootLLCI**	**BootULCI**
GT	0.0703	0.0422	0.0128	0.1489

CI = Confidence Interval, UL = Upper Limit, LL = Lower Limit

4.8 Summary of Hypothesis Results

TABLE 4.10: Summary of Hypothesis Results

Hypothesis	Statements	Status
H1	Green finance has a positive impact on economic growth.	Accepted
H2	Green finance has a positive impact on renewable energy.	Accepted
H3	Renewable energy has a positive impact on economic growth.	Accepted
H4	Renewable energy mediates between green finance and economic growth.	Accepted
H5	Green technology moderates between green finance and renewable energy.	Accepted
H6	Green technology moderates the indirect effect of renewable energy in such a way, higher green technology will strengthen the indirect impact of renewable energy on economic growth.	Accepted

4.9 Discussion

4.9.1 Green Finance and Economic Growth

The objective of this research is to examine the interconnection between green finance and economic growth. Results of Structural Equation Modeling reveal that green finance has a positive and significant impact on economic growth, which supports the hypothesis of the study H1. These results are consistent with past studies (Ngo et al., 2021; Nie et al., 2024), who also reported a positive influence of green finance (GF) on economic growth (EG). The results demonstrate that unit change in variable GF leads to a 0.223 units increase in economic growth, holding all other variables constant. As positive sign of the estimate reflects that there is

a significant and positive nexus among green finance and economic growth. The standard error of 0.059 and z-value 3.768 confirms its statistical significance with a p-value of 0.000, which is less than 0.05.

Countries that have invested in green financial instruments have not only witnessed substantial development in financial sector but also experienced robust economic growth. Investment in green financing is strongly interrelated with economic expansion and regulations related to green financing help to induce growth in the economy which consequently reduces carbon emissions (Cai & Guo, 2021).

Green financing instruments, including green credit exert a positive influence on a country's economic development in the long term and in near future. Similarly, the issuance of green bonds contributes to the long term economic development (H. Huang et al., 2023) and (Ntsama, Yan, Nasiri, & Mboungam, 2021) documented that issuance of green bonds have various economic and social benefits particularly refining the governance and reinforcement of social responsibility, both are regarded as a fundamental components underpinning sustainable development.

Policies related to green financing boosts the performance of the economy through the innovation of the technology (Fan & Zhang, 2024). According to the European Investment Bank (EIB,2021) environmentally friendly initiatives in EU develops employment opportunities that consequently leads to improve the progress of the economy.

4.9.2 Green Finance and Renewable Energy

An investigation into the relationship between green finance (GF) and renewable energy (RE) is carried out through structural equation modeling. The outcomes underscore that green finance positively and significantly influences renewable. This supports the hypothesis of the study H2. The results are in line with prior studies (Peng et al.,2023; Alharbi et al., 2023).

This indicates that one unit change in green financing investment is predicted to result in 0.204 which means a 20.4% increase in utilization of renewable energy. A positive and significant estimate indicates that higher levels of green financial initiatives contribute to a surge in renewable energy investment and development

of infrastructure of renewable energy. This validates the concept that financial incentives play a vital part in transforming energy to clean energy. When green financing increases, more funding is allocated to sustainable energy projects which leads to widespread usage of clean energy sources including solar, wind, hydro and biomass.

Chen et al. (2024) corroborate that banking system plays vital role in the contribution of green financing towards investments in clean energy and the banking sectors More funding by sustainable financing stimulates governments to go for investments in green energy which leads towards cost reduction. Moreover, the strong association predicts that policies related to green financing including green bonds and green loans are effectively directing capital into clean energy projects. (Cheng et al., 2023).

4.9.3 Renewable Energy and Economic Growth

The present study investigated the role of economic growth on renewable energy. The results of the structural equation modeling revealed that renewable energy has a positive and significant impact on economic growth. The results are in line with the study's hypothesis H3. The results are consistent with past studies (Zafar et al., 2019; M. M. Rahman & Velayutham, 2019; Shahbaz, Raghutla, Chittedi, Jiao, & Vo, 2020). The analysis has determined that one unit increase in economic growth predicted to result in 0.317 increase in renewable energy. A positive and significant coefficient indicates that higher the adoption of renewable energy, higher will be the rate of economic growth.

Investments in renewable energy sector can create employment opportunities and maximize income of labourers. Development in renewable energy sector fosters innovation and aids in industrial development (Borg et al.,2022, Pata et al.,2023).

According to Renewable energy projects lead towards the creation of jobs through installation and manufacturing that promote growth in economy by reducing unemployment. The transition towards the transformation of the energy system plays vital role in fostering growth in developing nations. According to Rusiadi et al. (2024) countries that are engaged in renewable energy adoption experience

higher growth. The development of renewable energy sector attract foreign direct investment as global investors are concerned about the attainment of Sustainable Development Goals. Higher consumption of energy leads towards maximized production which boost the growth in the economy. According to N. Singh, Nyuur, and Richmond (2019) production in clean energy promotes the development of firms that operate on a small scale and aids in creation of jobs in underprivileged areas of developing economies. Investing in renewable energy is advantageous for an economy in rural regions in the context of the installation of solar systems and wind farms.

Economies that invest in clean energy have less dependency on imported sources of energy, which in turn maximizes energy security and alleviates the economic risks related to the volatile international oil prices. Moreover, clean energy possess low costs related to maintenance as compared to nonrenewable energy resources. Renewable energy resources generated the new business opportunities and reduces the environmental degradation.

4.9.4 Mediating Role of Renewable Energy between Green Finance and Economic Growth

The present study investigated the mediating role of renewable energy between green finance and economic growth. The results of the structural equation modeling reveal that renewable energy fully mediates the relationship between green finance and economic growth. Outcomes are in line with the study's hypothesis H4. The results are consistent with earlier studies (D. Zhang et al., 2022; Gong, Ying, & Dai, 2023). The results reveal that one unit increase in green finance leads to 0.065 unit increase in economic growth via renewable energy, holding all other variables constant. Mediation effect is significant and positive which indicates that green financing not only have direct effect on economic growth but this effect is influenced by a mediator renewable energy. Green finance serves a key tool in facilitating the development of renewable energy infrastructure through. Y. Wang and Zhi (2016) explores that policies related to green credit contributes to the clean energy projects that in turn fosters growth in the economy. Through

green financing initiatives the financial constraints related to high initial investments cost of clean energy are minimized. Consequently, when renewable energy sector widens, it leads in providing numerous economic benefits. Development of the clean energy, broadens the market and job opportunities which lead to higher GDP growth.

4.9.5 Moderating Role of Green Technology Between Green Finance and Renewable Energy

Structural equation modeling is used to analyze the correlation between green finance and renewable energy with moderating role of green technology. The results reveals that green technology moderates the relationship between green finance and renewable energy which supports the hypothesis 5 of the study. These results are in line with prior studies (D. Zhang et al., 2022; Yin et al., 2023).

A coefficient of 0.260 characterizes the interaction term between green finance and green technology. This correlation indicates that in presence of green financial activities, a one unit rise in green finance is associated with 26% improvement in renewable energy investments. Given that the p-value for this interaction term is 0.000, exceeding the significance level of 0.05, it may be deduced that there is statistical evidence substantiating the relationship.

Both positive and substantial, the interaction effects suggest that green technology affects the link between green finance and renewable energy among developing nations. The available empirical data suggests that the presence of green technological innovation strengthens the interconnection among green financing and renewable energy resources. A strong and positive effect indicates represents that green financing operationalize well in economies where technological innovations are high. However, this highlights the significance of the policies that encourages R&D in ecofriendly technologies.

The results of this study indicates that existence of green technological innovations enhances the impact of GF on renewable energy. According to Zheng et al. (2023) green finance enhances the ecofriendly technologies but it contributes to one type of energy more i.e. wind energy. Green financing provides substantial funding for

clean energy, but its efficiency is subject to extrinsic factors such as technological innovations. Green technology comprises of wind turbines, solar energy and smart grids which improves the effectiveness, flexibility and access to renewable energy resources.

4.9.6 Moderating Role of Green Technology on The Mediating Effect of Renewable Energy Between Green Finance and Economic Growth

Structural equation modeling is used to examine the moderated mediation model. The results reveal that green technology moderates the mediating effect of renewable energy between green finance and economic growth which supports the hypothesis 6 of the study. Results in the table 4.9 shows the positive estimate of 0.0703, Boot SE 0.0422, BootLLCI 0.0128 and BootULCI 0.1489 which shows that no zero falls between them it indicates that the indirect effect of green finance on economic growth through renewable energy varies due to green technology. The significant and positive index of moderated mediation depicts that when green technology enhances, the indirect effect of green finance on economic growth through renewable energy also maximizes.

This moderated mediation relationship means that indirect effect of green finance on economic growth through renewable energy is dependent on the adoption of the green technology. It indicates that green technology strengthens the potential of renewable energy to transfer the advantages of green financing to economic growth. Consequently, when green technology is highly developed, the mediation effect is more prominent which leads to higher economic growth. Advancements in technological innovations minimize the costs associated with production of renewable energy while enhancing the effectiveness of green investments in propelling economic growth. The existence of higher green innovations lessens the risks related to clean energy projects.

Chapter 5

Conclusions

5.1 Conclusion

This study has analyzed the relationship between green finance, economic growth, renewable energy and green technology while investigating the moderated mediating impact by using structural equation modeling and panel data of 80 developing countries from 2000 to 2021.

Findings of this study revealed a positive and significant relationship between green finance and renewable energy. Green finance plays significant role in encouraging the adoption of renewable energy through allocating sufficient funds including issuance of green bonds for execution of renewable energy projects. Moreover, green financing assists in establishment of green energy projects including solar, wind, biomass and hydro through different financing initiatives like tax breaks and loans that do not include interests. Secondly, clean energy also has a positive and significant impact on growth of the economy. When an economy is focused towards development and implementation of clean energy, it will create more jobs related to the installation and maintenance of solar energy. Shifts towards the cleaner energy contributes to higher GDP and growth in the economy and reduce CO_2 emissions, environmental degradation and greenhouse gas emissions. Third, green finance has a positive and significant impact on economic growth. Green finance has catalyzed driving economic growth, especially in developing economies where accessibility to environmentally friendly investments is essential. Financial

instruments including green bonds and investments in other green instruments, encourage the economies to shift towards sustainability. Green financing allocates fund for sustainable projects, establishment of infrastructure.

The renewable energy has the indirect effect on green finance and economic growth. This advocates that green financing instruments such as green loan, green credit and green bonds contributes towards the adoption of the renewable energy sources which in turn increases economic growth. Green technology moderates between green finance and renewable energy which means green technology strengthens the nexus among green financing and clean energy. Economies or industries that are conscious of adoption of clean technologies tends to minimize the initial cost of production of green energies. The indirect effect of renewable energy between green finance and economic growth is moderated by green technology. It is observed that green technology strengthens the moderated mediation effect and indicates that environmentally friendly technologies effects the RE along with green financial initiatives that promotes the growth in the economy.

5.2 Policy Implications

From the empirical analysis, this study yields several key insights for policymakers to consider in promoting EG in developing economies. The results obtained from the impact of GF, RE on EG and the role of GT as a moderator and RE as a mediator are instrumental in crafting sound environmentally friendly policies. Governments in developing nations should encourage and incentivize the expansion of wide array of green financial instruments such as green bonds, green loans and specialized green equity funds. This can be done through the strategic application of fiscal incentives in the form of tax relief and subsidies for green project supplemented by the establishment of robust regulatory systems that stimulate green investments. Moreover, the consideration of setting up national or regional banks which would be helpful for raising funds for environmental projects, especially for those that might be at more exposure to risk by conventional lending organizations. In order to promote local as well as global private capital, it is essential to implement policies that mitigate the investments risks associated with

green investment including offering assurance of political risks and encouraging public private partnership (PPP) models.

The findings further analyze the strategic importance of RE in stimulating the economy while simultaneously showcasing the mechanisms through which GF exerts its developmental influence. This includes formulating particular policies related to green finance like tax credits and capital subsidies that specifically aimed to foster the adoption of solar, wind, hydro and geothermal energy projects. However, development and adoption of RE requires significant infrastructure investment in upgradation and expansion of grid to be capable of incorporating intermittent sources of RE while enhancing grid access for underdeveloped areas. Policymakers should set ambitious yet realistic national targets for the proportion of RE in the total energy mix, which will give the long term investors the certainty that they need to invest. The mediating function of RE between GF and EG is one of most important insights. Policymakers ought to develop the "Green Growth Roadmaps" that explicitly quantify the economic benefits of RE investments supported by green finance. This integrated approach shows that financial flows are not environmentally friendly but also play a key role in promoting growth in productive sectors through clean energy. The moderating function of GT between GF and RE highlights the urgent need for policy makers to create a thriving green innovation ecosystem. This needs substantial investment in green R&D along with the establishment of strong framework of intellectual property protection to attract and retain foreign investments in clean technologies. It is equally important that technology transfer policies emphasize adaptation and localization, ensuring the imported green technologies are not only adopted but are also integrated to meet local needs, thereby enhancing national technological capabilities.

Finally, high levels of GT indirect economic impact of RE presents powerful imperative for policymakers to strategically integrate technological advancement into the deployment of renewables. Prioritizing the environmentally friendly projects that incorporate cutting edge ecofriendly technologies such as advanced energy storage, advanced grid systems can improve the efficiency and reliability of renewable energy systems, create high skilled employment and facilitate the growth of the economy. Moreover, policymakers should actively engage in international

collaborations and central banks should carefully develop and offer specific environmentally friendly products. These alliances enable developing economies to actively participate in the development and dissemination of next generation green technologies, directly contributing to SDG 17 and SDG 13.

5.3 Limitations of the Study

Although this study offers valuable insights, there are several limitations that should be recognized, potentially affecting the interpretation of the results and indicating the areas for additional research. The research study has restricted time frame from 2000 to 2021 due to non-availability of the data. The attempts were made to extend the sample size but the data before the year 2000 of all variables were not available due to which it hindered the empirical analysis. However, the panel data capture trends over time and may not takes into account geopolitical risks. It does not provide insights on every country individually regarding the nexus between GF, RE, GT and EG. Moreover, the study emphasizes on the macro level perspectives that that overlook micro level aspects, that may offer deeper insights on specific perspectives. In addition, the research focuses on developing countries which may limit the generalizability of the findings.

5.4 Directions for Future Research

Despite these findings being useful to illuminate the interconnection between GF, GT, RE and economic growth, there are many directions for future research to be explored. In future, research can be conducted on developed economies, the comparative analysis between developed and developing economies to dive deeper into the study and in the context of specific countries to expand the scope and to capture broader trends. This research can be conducted considering other variables including FinTech and policy support and addition of a moderator or mediator in this theoretical framework. Alternative methodological approaches, other than SEM may also be applied to further test the robustness of the findings of the study.

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