The Impact of Natural Resource Rent, Trade Openness, and Institutional Quality on Green Growth

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Letter of Transmittal

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Dear Sir,

I am pleased to submit my research thesis, titled "The Impact of Natural Resource Rent, Trade Openness, and Institutional Quality on Green Growth" in fulfillment of the graduation requirements for United International University. This dissertation represents several months of extensive research conducted from August 27, 2024 to December 19, 2024, focusing on addressing energy poverty and advancing the movement toward peace and prosperity.

Under the honored guidance of Professor Dr. Md Qamruzzaman, I investigated the relationship between Natural resource rent, Trade openness, and Institutional quality in fostering influences in Green grwoth. I am profoundly grateful to Dr. Md Qamruzzaman for his invaluable support in shaping the research framework, refining the technical approach, and ensuring analytical consistency throughout the study.

I want to express my gratitude to United International University for providing the essential resources and support throughout the completion of this thesis. Additionally, I sincerely thank the international organizations and data providers whose valuable contributions furnished the necessary data for this research.

Lastly, I acknowledge that this work would not have been possible without the unwavering support and encouragement of my family, friends, and colleagues. I am profoundly grateful to each of them for helping me navigate challenges while maintaining a committed focus on the objectives of this research.

I want to express my gratitude for agreeing to evaluate my thesis. I look forward to discussing its conclusions and the potential impact of its findings.

Sincerely,

Abu Obaida Rumi

ID: 111 201 156

Abu Obaida Rumi

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Executive summary

Green growth represents a transformative approach to economic development that aligns economic progress with environmental sustainability and social equity. This concept gained traction in the late 20th and early 21st centuries due to the recognition of environmental degradation and climate change as critical global challenges. Popularized in the mid-2000s, particularly by the OECD, green growth involves sustainable resource management, transitioning to renewable energy, fostering a circular economy, conserving biodiversity, and driving technological innovation. Recent discussions have seen increased interest from policymakers and environmentalists in green growth as a means to tackle climate change, reduce resource consumption, and address social inequalities while maintaining economic growth. It seeks to decouple economic growth from environmental degradation, promoting a model where economic activities enhance rather than deplete natural capital. Central to green growth is the efficient use of resources, the adoption of renewable energy, and the advancement of sustainable technologies. This model emphasizes circular economy principles, where waste is minimized, and products are designed for reuse and recycling. While outcomes vary across nations, some have experienced positive results through technological innovation and improved environmental quality, while others face challenges in implementation. Green growth supports multiple Sustainable Development Goals (SDGs), particularly those targeting clean water, sustainable cities, climate action, and biodiversity conservation. It requires a combination of technological innovation, supportive policy frameworks, and financial incentives to foster sustainable development. In urban areas, green growth strategies focus on building sustainable infrastructure and improving transportation systems to mitigate environmental impacts.

This study explores the relationship between green growth and sustainable development, examining how factors like natural resource rent, trade openness, and institutional quality influence green growth and its environmental impact. The first objective is to investigate how green growth can bridge economic development, environmental protection, and social inclusion, promoting sustainable development that balances economic expansion with preserving ecosystems and advancing social equity. The second objective focuses on how green growth contributes to sustainable development through the efficient use of resources and meeting human needs without compromising ecological integrity. This approach emphasizes a shift from traditional economic models to a framework that harmonizes financial, social, and environmental well-being. The third objective examines the role of technology, policy frameworks, and institutional quality in implementing green growth strategies. By identifying pathways that align innovation, governance, and resource management, the study aims to understand how green growth can create synergies for a more equitable and resilient global economy in the face of environmental challenges.

The concept of green growth, which integrates economic development, environmental sustainability, and social inclusion, is central to contemporary sustainable development strategies. Three interconnected factors play a distinct role in shaping pathways to sustainable economic growth: natural resource rents (NRR), trade openness (TO), and institutional quality (IQ). Natural resource rents represent the economic returns from the extraction and use of natural resources. While well-managed resource rents can support eco-friendly infrastructure, excessive reliance on them can lead to the "resource curse," resulting in unsustainable practices and environmental degradation. Trade openness can drive economic growth through cleaner technologies and innovation diffusion, but it also presents environmental challenges, particularly in countries with weak regulatory frameworks. The net effect of trade openness on green growth depends on the composition of trade, technological capacity, and regulatory quality. Institutional quality is critical in determining whether NRR and TO contribute to sustainable development. Strong institutions enforce environmental regulations and manage resource rents effectively, while weak institutions can exacerbate environmental challenges. The interaction between NRR, TO, and IQ is complex and context-dependent. In developed economies, trade openness and effective use of natural resource rents can support green growth, while in developing economies, weak institutions can hinder sustainability efforts. This study emphasizes the importance of integrated policies that address the interplay between natural resource management, trade liberalization, and institutional development. Effective governance and sustainable resource management are essential for leveraging trade and natural resources for green growth. The methodology involves a comprehensive literature review to establish a theoretical framework and identify gaps, followed by empirical analysis using econometric models to examine the relationships between these factors and their impact on sustainable economic development. To investigate the impact of these variables on green growth, various econometric models, including Non-Linear Autoregressive Distributed Lag (NARDL), Two-Stage Least Squares (2SLS), and Autoregressive Distributed Lag (ARDL), among others, are applied. The analysis utilizes time series data to examine both short-term and long-term relationships between the factors and to test for causality and robustness of the results. This empirical approach aims to provide valuable insights into how these variables interact to influence sustainable economic development and environmental sustainability.

This study explores the relationships between natural resource rents (NRR), trade openness (TO), institutional quality (IQ), and green growth, synthesizing findings from empirical research to understand how these factors shape sustainable development outcomes. Natural resource rents can drive economic growth but may also lead to environmental issues, particularly in low- and middle-income countries. Under strong institutional frameworks, resource wealth can promote technological innovation and green growth, highlighting the importance of governance in resource exploitation. Trade openness can stimulate economic activity and technological exchange but may also result in environmental degradation. However, it can also facilitate the diffusion of green technologies, indicating complex dynamics. The effects of trade on sustainability are context-dependent, influenced by a country's economic development, regulatory environment, and trade relationships. Strong institutions characterized by transparency and effective governance are critical in mitigating negative environmental impacts. Good governance helps regulate economic activity and ensures that the benefits of trade and resource exploitation contribute to sustainable development. The literature emphasizes the interdependencies between these variables, suggesting that improvements in institutional quality can enhance environmental outcomes. Institutional strength can also mitigate the "resource curse," enabling countries to leverage their natural wealth for green development. Long-term relationships between NRR, TO, IQ, and green growth are affirmed, with institutional quality consistently showing a positive impact. However, the effects of NRR and TO on green growth are nuanced, with outcomes varying based on national contexts and governance structures. The findings highlight the need for well-designed policies that promote sustainable trade practices, manage resource extraction responsibly, and build institutional capacity to ensure economic growth aligns with environmental and social objectives. Ultimately, the study underscores the importance of an integrated approach to sustainable development, where governance, institutional quality, and trade and resource policies are aligned to foster green growth.

This research contributes to theoretical and practical domains by presenting a novel perspective on the role of natural resource rents in economic development and governance. It offers a comprehensive understanding of how resource wealth shapes political structures, socioeconomic outcomes, and environmental sustainability. The research extends the existing literature on the resource curse, emphasizing the roles of governance, policy implementation, and institutional quality in mitigating or amplifying the effects of resource rents. Additionally, the thesis provides actionable policy insights for resource-rich countries, suggesting ways to manage their natural wealth to promote sustainable development and reduce inequality. Through its interdisciplinary approach, the work advances academic understanding and offers a framework to guide policy formulation in resource-dependent economies, helping them transition to more resilient and sustainable development paths.

To enhance green growth, a multifaceted policy approach is needed. Sustainable resource management should be prioritized, ensuring natural resource rents are channeled into green investments and environmental conservation. Trade policies should encourage eco-innovation and reduce carbon footprints while supporting economic development. Strengthening institutional quality is crucial for effective governance and regulatory effectiveness. Financial incentives for green technologies, such as tax breaks and grants, would encourage industries to adopt greener practices. Public awareness and education on environmental issues should be a key focus, fostering a cultural shift towards sustainability. International cooperation should facilitate technology transfer and financial support, particularly to developing nations. Investment in green infrastructure and promoting a circular economy that prioritizes recycling and reducing waste are essential. Supporting the transition to renewable energy sources and expanding green finance mechanisms would facilitate a shift away from fossil fuels. Urban planning policies should integrate green spaces and energy-efficient buildings to reduce cities' ecological footprints. Finally, robust monitoring and evaluation systems should be established to track the effectiveness of green growth policies.

Keywords: Green growth, Natural resource rent, Trade openness, Institutional Quality, Anticipate, Economic

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List of Abbreviations

Abbreviations	Full Form
ADF	Augmented Dickey-Fuller
AMG	Augmented Mean Group
AGM	Akbari-Ganji's Method
ARDL	AutoRegressive Distributed Lag
BRICS	Brazil, Russia, India, China, South Africa
CADF	Cross-Sectionally Augmented Dickey-Fuller
CIPS	Cross-sectional Augmented IPS Test
DWH	Dynamic Weighted Harmonics
CS-ARDL	Cross-Section AutoRegressive Distributed Lag
CSD	Cross-Sectional Dependence
DOLS	Dynamic Ordinary Least Square
FDI	Foreign Direct Investment
FMOLS	Fully Modified Ordinary Least Squares
GDP	Gross Domestic Product
GMM	Generalized Method of Moments
PVA	panel vector autoregression
IQ	Institutional Quality
MG	Mean Group
OLS	Ordinary Least Squares
DF-GLS	Dickey-Fuller Generalized Least Squares
R&D	Research and Development
PGDP	Post Graduate Diploma in Psychotherapies
NRR	nitrogen reduction reaction
SDGs	Sustainable Development Goals
QR	Quantile Regression
TO	Trade Openness
MMQR	Modified Median Quantile Regression
2SLS	Two-Stage Least Squares
ML index	Machine Learning Index
BCSGC	Bayesian Cointegrating Structural Granger Causality
STIRPAT	Stochastic Impacts by Regression on Population, Affluence, and Technology
DARDLS	Dynamic Augmented Regression Distributed Lag
EKC	Environmental Kuznets Curve
GMM	Generalized Method of Moments

PARDL	Pooled Autoregressive Distributed Lag
SGSG	Stochastic Generalized Solow Growth
GET	Generalized Exponentiation Test

Chapter 01: Introduction

1.1 Background of the study

Green growth is an approach that integrates economic development with the protection of natural assets, providing the foundations for such growth. It is also a model of economic development that wants to maintain future growth with environmental protection and social attachment. It ensures that strategies in the economy, society and the environment mutually reinforce each other to promote robust growth while avoiding negative spillovers on the environment. More recently, from October 2023 onwards, a new variety of thinkers have tackled this issue as policymakers, economists and environmentalists look for ways to tackle climate change alongside resource reduction and social inequality whilst keeping the economy growing. It aims to release economic expansion from ecological damage, a mode of less ecologically damaging prosperity without making it unsustainable.

The study of Fay (2012) investigate that green growth is an economic fusion of development that aims to achieve sustainable development where, on the one hand, natural and energy resources are used cleanly and efficiently. Basic human needs for food, water, shelter, and other material consumption can be met, but environmental sustainability is not sacrificed as a consequence. This is a withdrawal from conventional economic models that typically favor development to profit, even at the cost of environmental manipulation. Another study of Hussain et al. (2022) the idea first emerged as a solution to the realization that many economic development models created negative externalities by harming the environment and causing us to use our resources. Green growth aims to reproduce a more sustainable and strong economic system by incorporating environmental considerations into economic processes.

The study of Fay (2012) shows that green growth is a concept developed in the late 20th and early 21st century, realizing that environmental degradation and climatic changes are emerging challenges. It originates in earlier concepts of sustainable development which came to the fore after the 1987 Brundtland Report. Another study of Fay (2012) express the term "green growth" began to gather drive in the mid-2000s, particularly in international development and environmental policy circles. The concept has gained currency and developed accordingly, with the Organization for Economic Co-operation and Development (OECD) playing a key role. More evidence found in the study of Sarkodie et al. (2023)OECD (2011) stated that green growth originated in the concepts of sustainable development (SD), which had arisen from the mid-1990s. The method gained greater prominence with the 2008 global financial crisis as countries sought new approaches to growing their economies and creating jobs. The Organization for Economic Cooperation and Development (OECD) officially endorsed and promoted green growth strategies.

The study of Sarkodie et al. (2023) finds that Green growth covers both an economic-related perspective, which seeks sustained economic growth through investment in green sectors, creation of green jobs, and boosting productivity through resource efficiency, and an environmentally based perspective to reduce environmental pressures, maintain natural capital, and enhance ecosystem resilience. This multilateral formulation brings us to a comprehensive understanding of sustainable development, wherein economic progress is consistent with environmental protection.

The study of Herman et al. (2023) figure out that sustainable resource management is at the heart of green growth, where natural resources must be used efficiently and sustainably.

Moving from Fossil Fuels to Renewable Energy. This method includes changing over out of fossil energizes and utilizing sustainable power sources, for example, sun based, wind and hydroelectric power, which would bring down carbon releases while additionally decreasing support on non-renewable assets. It also supports the Circular economy where recycling and reuse of materials contribute to minimizing extraction of resource and reducing environmental impact. Biodiversity conservation is also equally important; it focuses on protecting ecosystems and class diversity to ensure ecological balance creation and the availability of resources for future generations. Another study of Yikun et al. (2023) investigates that to grow green Technological innovation is one of the most unavoidable contributors; since it incorporates environmental protection through technology, which can help industries adopt sustainable and efficient approaches. Implementing cleaner and renewable energy sources, such as solar, wind, and bioenergy provides less reliance on fossil fuels and a reduction in carbon emissions leading to a greener economy. Furthermore, energy efficiency gains through devices from factories to transport systems further optimize resource use; less waste leads to lower costs for businesses and consumers. Innovating towards sustainable production processes will permit industries to transition into cleaner, less polluting processes. However, green infrastructure improvements like sustainable building products and modern waste management systems help to further develop solid and more sustainable neighborhoods. Sun et al. (2022) highlights green technology innovation is not only very critical for further reduction in carbon emissions but also very crucial to sustainable development, thus requiring a need to continue technological progress to achieve the goals of green growth. Study of OECD, 2011 "Resource efficiency is a guiding principle for green growth, emphasizing the need for natural resources to be used efficiently within production processes. That would involve waste reduction, increasing energy efficiency, and the sustainable management of key resources such as water, forests, and minerals. Resource efficiency has another effect whereby it minimizes resource inputs while maximizing output, reducing the environmental impact of industrial activities and cutting operation costs. This also encourages firms and industries to adopt more sustainable methods to save resources and add value toward economic flexibility in the long run. While meeting the high demand of the economies, efficient use of resources should be considered to minimise ecological damages, a factor that propels sustainable development. Another study of Shopina et al. (2023) and Perelli (2014) figure out that, green growth focuses on the rebuilding of degraded ecosystems and building greener infrastructure in order to maximize resistance and sustainability within an ecosystem. Examples are ecosystem restoration, like natural reforestation on abandoned agricultural lands, essential in recovering biodiversity, improving soil quality, and sequestering carbon. Research into post-acrogenic pine forest ecosystems depicts the favorable results of a self-restoration of nature, reviving local flora and fauna and providing for carbon storage to combat climate change. Besides, the green urban infrastructure provides a very practical solution to environmental problems in cities, such as green roofs. The primary functions of green roofs are related with stormwater management, reduction of urban heat, and energy consumption by providing natural insulation. These areas of green within an urban context provide various benefits to the natural environment, improving living conditions for city citizens by ensuring cleaner air and greener landscapes in highly populated city areas. Taken together, ecosystem restoration and green infrastructure create a sustainable urban and rural landscape that aligns with the goals of green growth.

The study of Ahmed and Elfaki (2024) finds that, the implications of green growth on the economy as being quite diverse and complex, with no consistently positive effects occurring across countries. The study informs against "win-win" scenarios from being assumed across all levels, since results showed mixed outcomes across different nations and indicators. This very significant green growth policy contributed differently to economic outputs such as energy intensity and technological development. Some countries realized positive impacts, while others probably suffered from the problems. Environmental tax policies have contributed to green innovation-creating new opportunities in economies like Japan, the UK, and the US-things that were inconsistent across all the studied economies. The outcome was ambiguous with respect to energy intensity and productivity growth, indicating that economic efficiency gains and productivity improvements cannot be taken for granted. These studies have also highlighted serious data gaps in measuring outcomes of green growth-that is, determinants of policymakers in order to calibrate policies for desired economic impact. With all these complexities and ambiguous short-run results, this study has implied that green growth strategies are critical for long-term sustainability in economic development joined with the preservation of a healthy environment. Another study of Zhang et al. (2024b) suggests that green growth strategies include fintech and renewable energy, which could further contribute to accomplishing improved environmental quality and achieve economic development. The study focuses on the green economic recovery of the BRICS economies and signals that these strategies are critical in ensuring economic restoration, especially within emerging markets. And including fintech suggests that technological advances and digital financial services are enabling green growth, potentially meaning new economic opportunities, efficiency. Taking natural resource rents into account would imply that strategies of green growth allow countries to better manage their natural resources. In contrast, the focus on renewable energy consumption indicates a shift toward much cleaner sources of energy with potentially wide-ranging implications for energy-intensive sectors. It probably informs about the balancing of economic growth and environmental protection, pointing to sectoral impacts and opportunities for international cooperation. The inclusion of fintech would also hint at the probable way in which evolution in the financial sector could be supportive of green initiatives. The study of Ashfaq et al. (2024) explores the relationship between renewable energy and green economic growth; therefore, green growth strategies may contribute to overall economic development and sustainable practices. The study narrows down to the renewable energy-economic growth connection, which suggests that a shift in the direction of renewable energy sources is quite fundamental to the concept of green growth and hence has great economic importance. Using dynamic ARDL modeling, the study probably gave insight into the long-term stability of the economy and, therefore, the sign for the policymakers on how to integrate the policy of renewable energy into the growth strategy. Green growth emphasizes a balance between economic development and environmental preservation, or big changes in the energy sector that have wide-ranging impacts across various industries. On the other hand, technologically advancing renewables could actually drive innovation and therefore new economic opportunities. In the study of Elfaki and Ahmed (2024) suggests that adopting digital technologies and globalization of innovation is able to contribute to environmentally sustainable economic development in Asian Pacific countries. By investigating their common relations, the research can explain how digital technologies create the conditions for innovation, productivity, and efficiency gains to support green growth and economic development. In this context, the term "green" may suggest a balancing between the advance of economic growth and the management of natural resources, which could affect the level of global competitiveness of Asian Pacific economies. The study can focus on ways through which digital technology and globalization contribute to regional economic integration and collective green growth strategies, highlighting sectoral transformations and the development of innovation ecosystems. Indeed, this will provide very valuable insights for policymakers in their endeavors to make use of digital technologies and globalization in such a way that they can help promote more sustainable economic growth, addressing long-term economic stability and development implications. Another study of Liu et al. (2024) investigate that green growth strategies driven by the digital economy can develop high-quality economic growth with simultaneous responses to environmental challenges such as climate change. In the digital economy, the contribution to a reduction in carbon emissions is very huge and an urgent need for meeting the carbon goals of China without delaying its economic growth. Digital trade is transformation conventional business and can enhance trade efficiency with reduced carbon footprints. This paper, then, identifies specific industrial clustering effects and associated carbon emissions to test the potential economic benefit derivable from sustainable industry. It introduces carbon emissions trading markets as a policy tool, working interactively with digital business to help develop new economic opportunities. The study investigates geographical differences in the relationship between digital economy growth and green growth, which can be interpreted as indicating differences in regional economic impacts. It focuses on technology gains and how the quickly growing importance of the digital economy is contributing to green progress; some opportunities in green technology markets are identified. The study of Yang and Long (2024) investigate the effect of transitioning to renewable energy on sustainable economic recovery. They consider that transition to renewable energy would provide an economic growth effect through maintaining environmental sustainability and using resources more efficiently. A transition of this extent in the energy sector would indicate broad changes in the use of energy and wide-ranging effects on the economy in various industries; therefore, the balance between economic development and protection of the environment is considered essential for stability in the long term. The study probably provides the necessary insights into how natural resource management and effective renewable energy policy implementation can be done as part of implementing sustainable growth smoothly. This transformation towards renewable energy is also likely to drive technological innovation, creating new economic opportunities and enhancing global competitiveness for economies applying green growth strategies. The latter might therefore enhance economic resilience in response to global challenges and impinge differently upon the various sectors of economics. In line with the above, it considers sustained economic possibility in approaches towards green growth, therefore taking a long-term perspective on implications of renewable energy transition to natural resource management. In the study of Manigandan et al. (2024) suggests that green growth strategies with effective natural resource management and green innovations, combined with well-designed environmental policies, have the potential to foster sustainable economic development in India. Green innovations are highlighted as the drivers of sustainable economic growth; so, this concludes that investment in environmentally friendly technologies is an added advantage economically. The study also reviews into the area of environmental policy deployment and through the findings, appropriate regulations encourage economic growth rather than discouraging it. Including financial development within this study suggests that a complete financial system makes green growth and sustainable economic development much easier. This may be the way to realizing economic growth while simultaneously responding to the call for the care of the environment, and thus achieving sustained economic stability and flexibility. Though not explicitly mentioned in this text, this emphasis on natural resources and green innovations could imply that there is a differential impact for different economic sectors. This study would, in all probability, also be a good guide for policy makers on how to, actually implement green growth strategies. Although it focuses on India, the findings might have implications for other developing economies trying to balance economic growth with environmental sustainability. In another study of Yu et al.

(2024) examines how resource rents influence green growth-suggesting that effective management of resources is critical in the development of sustainable economic development. It focuses on economic stability, thus suggesting that strategies for green growth may result in a strong economy in the long term. The mention of the "legal landscape" concludes that enabling legal environment is cardinal in the attainment of sustainable development. The research probably offers some input on how policymakers can make informed choices in the way resources are associated within economic stability and environmental protection through enabling frameworks. It suggests there could be a shift in economies toward more sustainable practices and maybe even how institutional quality could influence the association between resource rents and green growth. It could, therefore, address regional differences in resource contribution and their impacts on green growth across various provinces. This is likely to discuss how the greening of the Chinese economy affects the economic system and performance as a whole, and could investigate in depth the role of technological innovation in driving economic development. It probably explores the long-term economic prospect for China, under a green growth model, by linking resource rents, economic stability, and green growth.

The concept of "green growth" has been an important part in the context of achieving sustainable development; it is defined as development economic growth and development while ensuring that natural resources continue providing services that people depend on for well-being and happiness. Green growth" strongly links with the SDGs, which all UN member states agreed to in 2015. The SDGs are said to resolution issues related to the world, such as poverty, injustice, climate change, damage to the environment, lack of justice, and peace. Green growth contributes a great deal towards achieving several of the Sustainable Development Goals, through encouraging environmentally-friendly business practices and discovering that new green technologies are subtle and there is no real economic harm due to environmental concerns. Study of Batova et al. (2022) and Sơn (2021) finds that, Green growth has an important contribution to achieving the Sustainable Development Goals through economic development that is environmentally sustainable and socially inclusive, a trend which goes along with the generally taken development of building a wealthy society with an emphasis on ecosystem and sustainable use of natural resources, first of all in conditions of climate change.". Contribution of green growth to SDGs.

The study of Acosta et al. (2020) suggests that, green growth contributes significantly to the accomplishment of SDGs because of its aligning with a number of targets of the SDGs and providing a roadmap toward sustainable transition. The Green Growth Index, which benchmarks performance across countries, draws many indicators directly from SDGs, especially in the natural capital protection dimension, contributing to SDGs on clean water (SDG 6), sustainable cities (SDG 11), climate action (SDG 13), life below water (SDG 14), and life on land (SDG 15). By benchmarking against SDGs, allows countries to more effectively measure their progress and, therefore, increase policy significance to allow complete strategies by policymakers, which would promote environmental sustainability, economic growth, and social inclusion. Another study of Adamowicz (2022) suggest that it gives a general framework that combines economic growth with environmental protection and social inclusiveness. It is directly and indirectly related to several of the SDGs, including economic growth, poverty reduction, employment, social inclusiveness, environmental sustainability, clean energy and water access, and climate action. Green growth represents a "revolutionary new development model" and evaluates economic development against environmental and social concerns-an approach fitting for the integrated nature of the SDGs. It serves as a policy tool for the implementation of SDGs, and it is targeted toward long-term sustainability; thus, making it the most vital approach towards solving several interconnected development challenges. Green growth, according to GGGI, refers to a model that decouples economic growth from climate and environmental flexibility targets in different features of sustainable development. Another study of Belmonte-Ureña et al. (2021) finds that, in relation to the UN Sustainable Development Goals, it plays an essential role in developing economic growth through environmentally protective investments. While GG is mostly contributing to research among all 17 SDGs, it primarily emphasizes SDG 8 and SDG 13: Decent Work and Economic Growth, and Climate Action correspondingly. GG increases faster than average since 2011, the volume of SDGR and CE is greater than that of GG. In common with other domains, research in GG exhibits sparse coverage over some SDGs, especially SDG 1, No Poverty; SDG 5, Gender Equality; SDG 14, Life Below Water; and SDG 17, Partnerships for the Goals. The study of Yikun et al. (2023) found that green growth promotes economic development while ensuring that the environmental services and natural resources are available on a continuous basis for human well-being. It greatly encourages long-run environmental sustainability, helps reduce carbon emission levels, and has positive impacts on environmental sustainability in the long term. The green growth policies have positive impacts on employment in social development, creating more green economic sectors. If job transitions are managed effectively, the green economy has considerable potential for short-run growth. Green growth also tends to be closely linked with economic growth and technological innovation; innovative green technology improves green growth while reducing CO2 emissions significantly in the long run. Governance tends to be another factor that influences the effectiveness of green growth in achieving SDGs, having proper and effective governance as well as green growth observed as essential long drivers of SDGs. With good governance, nations are able to eliminate opposing impacts and consequences on CO2 emissions, as far as overall development is concerned. Another study of Sungkawati (2024) suggest that, by fostering sustainable development, improvement in human well-being, and reduction in environmental risks. It focuses on importance sectors such as renewable energy, resource-efficient construction, clean transport, sustainable agriculture, and eco-friendly technology development. Green economic policies highlighted resource efficiency, social inclusiveness, and high-quality employment, therefore directly contributing to SDG 8. Other activities in the area of environmental sustainability include recycling and valuing ecosystem services. The study of Saqib et al. (2024) figures out that, DG-7 and SDG-13 are particularly intended to address environmental issues with economic growth in a sustainable method for the purpose of environmental improvement, efficient use of resources, mitigation of climate change, and the creation of renewable energy. Green growth policies promote clean technology distribution, enabling a trade-off between economic growth and the protection of the environment. It focuses on increasing resource efficiency and environmental cleanness, which enables the broader goals of SDGs. Systematic policy design and institutional structures are highlighted in promoting green growth, while suggesting that supportive governance frameworks are one of the fundamentals for achieving SDGs. It promotes resource efficiency, greener technologies, and sustainable economy practices, bridging economic development and environmental sustainability in significant contribution to attaining Global Sustainable Development Goals. Another study of Yang et al. (2024) finds that, it achieving Sustainable Development Goals, especially the focus on SDGs 6, 7, 9, 12, and 15. The study improves to the inclusion of SDGs in regional green development analysis as a measure in order to avert ecosystem degradation and enhance transformational change. Meanwhile, on the basis of the green development index-ecological footprint analytical framework, study has performed an analysis related to the coupling relationship, decoupling relationship, and resistance relationship of relevant factors. From 2007 to 2016, Shaanxi Province expresses an average annual decline in ecological footprint by 5.45%, while the green development index shows an average annual growth of 4.78%, with an average annual coupling coordination degree of 0.69. In spite of these, the study has set a weak decoupling state and concern about energy consumption. The results show that green growth contributes significantly to attaining SDGs by balancing ecological protection with economic development and that targeted policy and coordination mechanisms are essential in promoting regional sustainable development.

Green growth is a development strategy that uses a combined approach to balancing economic progress with the realization of protecting natural resources. The discussion on green growth has gained attention from global performers as more and more countries realize the need to make a shift toward a more sustainable model of economic development. There are a number of important elements driving green growth, each playing a very important role in creating an enabling economy-one which can grow but at minimal cost to the environment.

Technology allows, for example, the efficient use of available resources, minimization of generated waste, or even the development of cleaner ways to source energy. Green technologies, such as renewable sources of energy-solar, wind, and hydropower; machinery that is energy-efficient; and carbon capture technologies-are quite basic in reducing environmental impact resulting from industrial activities. Study of Mingkai et al. (2023) have shown that the level of technological innovation in a region relates directly with the level of green growth experienced within the same region. For instance, in China's Chengdu-Chongqing Economic Circle, green technology innovation was identified as one of the key drivers that improves urban ecological environments. Also, the spatial implications effects brought about by technological development further enhance regional green growth through increased knowledge sharing and collaboration. Besides, the connectivity of digital economies with green technology further increases the potential for sustainable development. Digital tools could provide improved monitoring and optimization of resource use, hence their efficiency at reduced waste.

Study of Agan and Balcilar (2023) investigates the positive link between green growth that, technological innovation is good when government policies are favorable, involving incentives to research and development, supports toward green technologies, and regulations that will drive industries into greener technologies. Another study of Yu and Guo (2023) finds that, Innovation in green technologies can decouple economic growth from environmental degradation. For example, renewable energy technologies like solar and wind power reduce dependence on fossil fuels while supporting economic expansion. Further evidence finds in the study of Zulkefli et al. (2024) which expresses, Access to finance is essential for climbing up technological innovations. Green finance mechanisms such as green bonds or venture capital for clean tech startups can provide the necessary funding for innovation. On the other hand in the study of Zulkefli et al. (2024) which investigate the negative link between green growth that, Economic policy uncertainty can hinder technological innovation by creating an unpredictable environment for investment in R&D. Businesses may be reluctant to invest in new technologies if they are unsure about future regulatory or economic conditions. While technological advancements often aim to improve resource efficiency, rapid technological progress can sometimes lead to increased consumption of resources (rebound effect), negating some of the environmental benefits. For example, more energy-efficient appliances may lead to increased usage, thereby offsetting the efficiency gains.

Other key factors of green growth include government involvement through policies and regulations. Indeed, government policies can help create an enabling environment for sustainable development by encouraging clean energy use through the control of emissions and offering incentives for green investments. Study of Deng and Wu (2023) and Ma et al. (2022) finds that, "stringent environmental regulations drive industries toward cleaner technologies and practices.". These regulations often include limits on carbon emissions, water usage, and levels of pollution. Government support for environmental regulation, through forcing industries to observe higher environmental standards, has been shown to promote green technology innovation in the Yangtze River Economic Belt of China. Another study of Ağan (2023) suggests that, Financial incentives such as tax breaks, subsidies for renewable energy projects, and grants for research into sustainable technologies encourage businesses to invest in greener practices. In OECD countries, financial development has been found to positively impact green growth by providing necessary funds for environmentally sustainable technologies.

Study of Agan and Balcilar (2023) investigates positive link between green growth that, supportive government policies are critical in fostering technological innovation. Environmental regulations can act as a catalyst for industries to adopt greener technologies. Campaigns and education program led by the Government can create awareness among people for environmental issues which causes a change in their behavior that favors green growth. Regulations that support eco-labeling or carbon taxes which inspire consumers and companies to act less wastefully. Another evidence found in the study of Rasheed et al. (2023), Incentives such as tax breaks for green investments offered by the state can stimulate financial markets, or carbon trading systems that create an environmental goods market. Also, in the Study of Yu and Guo (2023) figures out negative link between green growth that, Sometimes they may slow the pace of natural resource-extractive and industrial-based economic growth due to strict environmental regulation. For example, industries dependent on fossil fuels may face higher costs due to carbon taxes or emission caps. Another study of Hameed (2020) finds that, Rapid urbanization without adequate planning can lead to environmental degradation despite government policies aimed at sustainability. In many cases, policies lag behind the pace of urban expansion, leading to issues like air pollution and inefficient waste management systems.

The structure of the economic growth itself significantly contributes to the purpose of sustainable development. Traditional models focus on the maximization of profits in the short run and are known to further resource reduction and environmental degradation. Green growth models imply dematerialization of economic growth. Study of Chen et al. (2024) investigates that, Inclusive green growth ensures that economic benefits are widely shared while there is a minimum negative impact on the environment. This is particularly important in the rural settings where sustainable agriculture practices reduce deforestation and soil degradation, improving livelihoods. Another study probed how a mix of digital transformation and inclusive green growth has managed in terms of economic development and environmental sustainability in rural parts of China. Another study of Hu et al. (2023) suggests that, A circular economy model highlights the reduction of waste by reusing materials and recycling products toward the end of their life. This model challenges that of the traditional linear economy model of produce-use-dispose and is increasingly considered to be one of the ways toward achieving sustainable economic growth.

Study of Agan and Balcilar (2023) finds positive link between green growth that, Transitioning from traditional economic models to those focused on green growth often involves integrating green technologies into production processes. This shift not only reduces environmental harm but also creates new economic opportunities in sectors like renewable energy. Another study of Yu and Guo (2023) finds that, Economic models that emphasize recycling and reusing materials (circular economy) align well with green growth objectives by reducing waste and conserving resources. Another study of Yu and Guo (2023) investigates negative link between green growth that, traditional economic models focused on maximizing short-run profits, which might run counter to strong environmental regulations. In other words, resource removal or highly polluted industries might oppose regulatory changes due to the increase in operational costs. Another study of Alsaggaf (2024) finds that rapid population growth can place additional problems on existing economic models through higher demands on energy and water resources. If not managed through sustainable practices, this results in overexploitation of such natural resources.

Urbanization can become both a source of difficult situations and opportunities regarding green growth. It can be explained by the following: on the one hand, rapid urbanization can contribute to higher levels of pollution and resource use; however, on the other hand, it opens possibilities for applying various sustainable solutions in terms of infrastructure. Study of Gao et al. (2020) suggest that, the construction industry contributes much to carbon emission because the industry requires a huge amount of energy input. However, the development of green structures of buildings that are designed to minimize energy use has become a key focus area in promoting sustainability within urban environments. Green buildings reduce emissions by designing efficient buildings, using sustainable materials, and mixing renewable sources of energy. Another study of Hu et al. (2023) finds that, urban areas are usually marked with seriously blocked roads and damaged air because of their dependency on fossil fuel-based transportation systems. However, electrification of transport systems, increasing public transport networks, and facilitating non-motorized transport modes such as cycling form crucial strategies for Carbon footprint reduction in urban areas.

Study of Hameed (2020) finds positive link between green growth that, urbanization is giving room for establishing environmentally well-suited transportation methods such as EV and public transit networks. These modes of transportation have the capacity to reduce carbon emissions and create a more sustainable air in urban centers. Urban centers are ideal points where standards of green building can be applied to reduce energy consumption, hence developing sustainably. In another study of Zulkefli et al. (2024) investigates negative link between green growth that, rapid urban growth often leads to inefficient use of resources and inappropriate infrastructure development. For example, high flow of traffic overcrowding, sub-optimally designed cities, and financial development come first in providing finance for urban infrastructure projects. It also leads to assumption in unsustainable real estate investment, hence contributing little to long-term green growth goals.

Access to finance is critical in supporting green investments in technology and infrastructure. The role of financial institutions in that direction is essential through the offering of capital to such projects that would be of help in environmental sustainability. Study of Ağan (2024) finds that, Green finance requires financial investments that make contributions to projects for positive environmental outcomes. This involves funding renewable energy projects, energy efficiency infrastructure developments, and sustainable agriculture-related initiatives. The financial development significantly contributes to green growth through the investment in environmentally friendly technologies in OECD countries. Carbon pricing mechanisms, whether it is carbon tax or cap-and-trade, provide a financial incentive for the enterprises to reduce GHG emissions by putting carbon pollution at a price. Essentially, what these markets do is to create financial incentives for firms to invest either in cleaner technologies or to buy carbon credits from firms that are more efficient.

Study of Yu and Guo (2023) finds positive link between green growth that, financial development is an important factor in financing R&D into green technologies. In easily available capital markets, businesses can provide financing for cleaner methods of production or renewable energy projects. Governments can also utilize the financial markets by giving tax breaks or subsidies on green investments. This is a rather favorable situation for firms that seek capital to finance sustainable projects. In the study of Rasheed et al. (2023) investigates negative link between green growth that, the fact that economic policy uncertainty could unfavorably influence financial markets by discouraging investments in long-term projects, such as those involving renewable energy infrastructure or clean technology startups. This may also be the case in regions characterized by rapid population growth, where the modes of financial development manage the long-term goals of sustainability in search of short-term gains, thereby getting invested in industries that are not environmentally smart.

It is a matter of climate change that requires international coordination. The contracts, agreements, and partnerships allow countries to share their experience and assist developing nations financially in achieving global sustainability goals. One of the biggest international treaties in addressing climate change is the Paris Accord. It contains targets for the reduction of global greenhouse gas emissions in order to keep global warming at 2 °C (3.6 °F) greater than pre-industrial levels or, preferably, below 1.5 °C (2.7 °F). Global Green Growth Institute (GGGI): GGGI is an inter-governmental organization that works with governments across the world to design strategies that facilitate green growth and overcome the socio-economic challenges of individual countries.

Study of Safronova and Barisa (2023) suggests positive link between green growth that, Transfer of technology between nations is made smoother through international cooperation and makes it possible for developing nations to adopt advanced green technologies faster than they can with only domestic innovation. For example, international partnerships have been a vital means to disseminate renewable energy technologies worldwide. There's also a negative link between green growth that, international trade agreements aimed at liberalizing markets sometimes functionally make economic growth the priority over environmental protection. If not properly managed with environmental regulations, this can contribute to increased resource extraction or pollution.

A key aspect of providing that demand on the supply side is public awareness about the need for sustainability. With consumers now more aware of their ecological footprint, demand for green products is on the rise. Eco-labels are on-products labels providing information on the environmental impact of a product. Such labels also help consumers make informed choices and in turn, this aids demand of sustainably produced goods. More organizations are taking on CSR initiatives as a business strategy focused on reducing their ecological footprint. This change is driven by consumer interests in greener products and regulatory pressures.

There is a positive link between green growth that, public awareness campaigns usually work in combination with government policies designed to promote greener lifestyles. Such as eco-labeling initiatives that provide consumers with the information needed to make informed purchases. Also, there's a negative link between green growth which shows that, despite increasing awareness in the general public regarding issues of sustainability, patterns of urbanization often will outgrow changes in behavior shaped by decade's worth of habits like car dependency.

Another key driver of green growth is decoupling: improving resource efficiency, using less resources per unit output. It minimizes waste creation for a given level of production or even raises technological productivity, wherein fewer natural resources will be required. These measures achieve the same level of performance by using less energy. It can be done via technological innovations like renovating machinery or industrial processes. With the increase in population and droughts triggered by climate change, water scarcity is becoming a more serious global problem. For example, the widespread adoption of drip irrigation systems by farmers or water recycling technologies in industries are all excellent practices of efficient water management which can go long way toward upgrading such challenges. Its finds out the positive link between green growth that, All the natural resources acquired by producer should effectively use in such a manner that no wastage (wastage of water, energy etc) will arise and ultimately nature burning process will be down. Energy efficiency measures lower greenhouse gas emissions while maintaining economic productivity. Water management techniques, such as drip irrigation, preserve the scarce resource and, in turn, contribute to agricultural productivity.

The population growth rates, migrations, and urbanization trends establish a changing demand on resources and the environment, which is reflected in population dynamics. Many problems related to human health are traced to a growing urban population as humans migrate to cities in search of broader and better economic opportunities, while the city systems in the form of water supply networks or waste treatment sites are hard-pressed by the increasing demand. With the fast aging of populations in certain parts of the world, such as Europe or Japan for example, due to increasingly lower birth rates combined with higher life expectancy rates, this demographic shift provides special opportunities tailor-made policies designed specifically to reach elderly populations themselves, so they keep contributing positively. There is a negative link between green growth that, Rapid population growth increases demand on resources, such as energy, water, and food, which puts further stress on natural ecosystems. With high population concentrations or large inward migration to cities, infrastructure overload drives unsustainable deforestation or an over manipulative concept of water resources.

1.2 Objective of the study

The primary purpose of this study is to examine the complex relationship between green growth and sustainable development. The study focuses on how natural resource rent, trade openness, and institutional quality affect green growth. And try to show or highlight how (positively or negatively) these variables affect the environment.

Objective 1: To examine the relationship between green growth and economic development, ensuring environmental protection and social inclusion.

The objective is to explore strategies for integrating economic development with environmental protection and social inclusion, aiming for sustainable growth patterns. This entails identifying methods that promote economic expansion while minimizing ecological harm and ensuring long-term development that benefits all sectors of society. The focus is on creating a balanced approach that harmonizes the needs for economic progress, environmental conservation, and social equity, ensuring that development is inclusive and resilient to future challenges.

Objective 2: To investigate how green growth supports sustainable development by efficiently using resources and meeting basic human needs without compromising environmental sustainability.

The objective is to examine how green growth can drive sustainable development by promoting the efficient and responsible use of natural and energy resources, ensuring that basic human needs such as food, water, and shelter are met without compromising environmental sustainability. This approach represents a paradigm shift from traditional economic models, which often prioritize profit over ecological preservation, to a more holistic framework that balances financial, social, and environmental well-being. The goal is to identify pathways that enable long-term development by fostering innovation in resource management, reducing environmental impacts, and supporting inclusive growth that benefits all communities.

Objective 3: To analyze how technology, government policies, and institutional quality impact the implementation of green growth strategies in different economies.

The objective is to explore the role of technological innovation, government policies, and institutional quality in shaping the successful implementation of green growth strategies across diverse economies. This involves investigating how advancements in digital technologies, the adoption of renewable energy solutions, and the development of effective policy frameworks can foster sustainable economic development while ensuring the preservation of natural resources. The focus is on understanding how these factors interact to create synergies that promote environmentally responsible growth, social inclusivity, and long-term resilience, while addressing the unique challenges and opportunities in different geographical, political, and economic contexts. The aim is to highlight pathways that align technological progress, governance, and institutional frameworks to create a more sustainable and equitable global economy.

Chapter 02: Literature review, Hypothesis development, and Research Gap

2.1 Literature Review

2.1.1 Natural resources rent effect on green growth

The study of Zhang et al. (2022), which investigates the impact of green investment, natural resources, green technology innovation, and economic growth on China's ecological footprint from 2000 to 2018 by employing NARDL model. Findings show a positive relationship between these factors and ecological footprint. Further evidence can found in the study of Chau et al. (2022). Study disclosed, providing theoretical and practical implications for policy formulation. Additionally, more evidence can found in the study of Liang et al. (2024). Study disclosed, found a positive association between natural resource rent and green finance, indicating the need for policies promoting sustainable resource usage and environmental conservation. Moreover, evidence can found in the study of Cheng et al. (2020). Study disclosed, abundant natural resources lower green total factor productivity, and resource industry dependence inhibits growth. Additionally, more evidence can found in the study of Li et al. (2022). Study disclosed, economic growth and the rent of natural resources have good effects on ecological footprint, while green innovation encourages sustainability.

The study of Alsagr and Ozturk (2024), which investigates the impact of resource rent and institutional quality on green investment in 51 top green investing countries from 1996 to 2021 by employing 2SLS model. They find that resource rent negatively impacts green investment, while political stability, government effectiveness, corruption control, rule of law, and regulatory quality boost it. Further evidence can found in the study of Khan et al. (2020). Study found that, natural resource rent negatively impacts financial development, while institutional quality boosts development and moderates the relationship. Further evidence can found in the study of Fu and Liu (2023). Study disclosed, natural resources asymmetrically influence sustainable development, with mineral rents and natural gas rents positively affecting and forest rents negatively. Additionally, more evidence can found in the study of Khaddage-Soboh et al. (2023). Study disclosed, a negative association between natural resource rents and CO2 emissions, but a positive relationship at higher quantiles. Moreover, evidence can found in the study of Huang et al. (2023). Study figures out, higher financial development, urbanization, and natural resources increase environmental pressure on the economy.

The study of Zhou et al. (2024), which presents two models for environmental sustainability, based on panel data from Brazil, Russia, India, China, and South Africa (BRICS) from 1994 to 2018 by employing use TFP model. It suggests that total factor productivity and renewable energy consumption improve environmental quality, but economic growth and natural resource rents are detrimental. Further evidence can found in the study of Shahid et al. (2024). Study disclosed, co-integration between these variables and uni-directional causality, suggesting the effectiveness of these policies on China's GTFEP. Additionally, more evidence can found in the study of Chen et al. (2023). Study shows that, institutional quality mitigates CO2 emissions by combating corruption and upholding the rule of law. Moreover, evidence can found in the study of Mumuni and Mwimba (2023). Study disclosed that, green energy consumption has both short-term and long-term growth-limiting effects, while CO2 emissions have positive impacts. Further evidence can found in the study of Li et al. (2024a). Study figures out, GPR positively impacts economic growth, while green finance and commerce boost growth across all quantiles.

The study of Gyamfi et al. (2022), which uses second-generation empirical methodologies to examine the impact of natural resource rents and energy consumption on the environmental quality of G7 economies by employing QR, AMG, FMOLS and DOLS model. Results show a positive relationship between total natural resources rent and pollution, with renewable energy consumption negatively affecting the environment. Additionally, more evidence can be found in the study of Tachega et al. (2024). Study disclosed, traditional and renewable energy efficiency are low, and economic expansion has significant environmental costs. Further evidence can found in the study of Huang and Guo (2022). Study disclosed, significant positive correlation between these factors, with financial development contributing to carbon emissions in the long term. Moreover, evidence can found in the study of Nguyen et al. (2024). Study found that, regional development, green innovation, natural capital, and natural resource rent positively contribute to environmental performance, while FDI has a negative effect. Further evidence can be found in the study of Ramzan et al. (2018). Study disclosed, a positive and significant effect of total natural resources on GDP per capita, with two co-integrated equations.

The study of Debonheur et al. (2024) which investigate the impact of natural resource rents on human development in 41 African countries from 1996-2019. Results show total rents negatively affect development, but food imports mitigate this. Rent types, such as forestry and natural gas, have different effects. Another evidence can be found in the study of Öztürk et al. (2023) which investigate the dynamic causal relationship between economic growth, renewable energy consumption, and CO2 in the G7 economies from 1997-2019 by employing PVAR model the study disclosed, a unidirectional causal relationship between GDPPC, CO2 and REN, with no significant relation between CO2 and REN. Moreover, evidence can found in the study of Ngo (2024). Study disclosed, abundant resources negatively affect GTFP, particularly in regions with higher green production. Further evidence can be found in the study of Shen et al. (2021). Study disclosed that, positive effects of energy consumption and financial development on carbon emissions, while green investment is negatively linked to CO2. More evidence can be found in the study of Ma (2024). Study disclosed that, globalization negatively impacts regional emissions, but economic development and green finance positively correlate with CO2 emissions.

The study of Chen and Chen (2024) which investigate the impact of natural resources rent, digital finance, and the combined effect of these factors on carbon emissions from 1990-2022 by employing ARDL model. Results show natural resources increase emissions, while digital finance reduces them. Policymakers should discourage natural resource extraction. Moreover, evidence can found in the study of Zhang et al. (2024b). Study disclosed, fintech and NRR improve economic recovery but harm environmental quality. Further evidence can be found in the study of Akadiri et al. (2023). Study figures out, policymakers should consider these factors when formulating environmental policies to mitigate climate change effects. More evidence can be found in the study of Wang et al. (2024c). Study disclosed, TRA significantly affects environmental quality, with higher natural resource rents improving ecological quality and higher levels of corruption controlling pollution reduction.

The study of Wang et al. (2024a) which investigate the role of natural resources in South Asian countries' carbon neutrality from 1990 to 2021 by employing DF-GLS, Phillip perron model. It finds that financial development and educational expenditure contribute to environmental degradation, while natural resources, renewable electricity, and R&D expenditure reduce emissions. Additionally, more evidence can be found in the study of Ma et al. (2024a). Study figures out, a negative association between ecological footprint renewable energy, technological change, ecological policies, and taxes. Further evidence can be found in the study of Okolo et al. (2024). Study disclosed that rents, including oil and natural gas, significantly promote innovation. More evidence can be found in the study of Udemba et al. (2024). Study disclosed, a positive association between fuels and carbon emissions, while economic growth and natural resources improve the environment. Further evidence can be found in the study of Hacıimamoğlu and Cengiz (2024). Study finds that, EKC hypothesis and show that REC and NRRs reduce environmental degradation. More evidence can be found in the study of Jin and Zafar (2024). Study discloses that, natural resource depletion, human capital, and economic growth significantly facilitate the transition, while financial development impedes the transition from traditional fossil fuels to green energy resources. Moreover, evidence can found in the study of Appiah et al. (2024). Study disclosed that, innovation decreases extraction, while FDI expands it. However, innovation independently increases extraction. Another evidence can be found in the study of Luo et al. (2023). Study discloses that, a strong positive correlation between natural resource rents and carbon emissions, especially in low-income countries.

2.1.2 Trade openness effects on green growth

The study of Tariq et al. (2024) which investigates the impact of eco-innovation, green trade openness (GTO), and carbon price on green growth (GG) and low-carbon emissions in emerging economies from 1996-2021 by employing standard green Solow growth model, the study found that positive shocks in these factors mitigate carbon emissions and promote green economic growth. Negative shocks cause environmental degradation and reduce GG. Additionally, more evidence can found in the study of Qing et al. (2024). Study disclosed that, environmental degradation negatively impacts GEC, while oil prices and economic development positively affect it. More evidence found in the study of Wang et al. (2024d). Study finds that, trade openness increases emissions, while trade diversification reduces them. Another evidence found in the study of Ibrahim et al. (2022). Study figure out that, long-run cointegration among variables, only adverse effects of renewable energy and technology can mitigate emissions. Further evidence found in the study of Ghazouani and Maktouf (2024). Study finds a bidirectional link between natural resources, economic growth, and CO2 emissions, and a unidirectional link between trade openness and CO2 emissions. Another evidence found in the study of Wang et al. (2024e). Study suggest, AI promotes energy transition and reduces carbon emissions, with trade openness playing a mediating role.

The study of Afjal and Devi (2024) which investigate the relationship between economic growth, renewable energy, and trade openness on CO2 emissions in OECD countries from 1995 to 2020 by employing panel vector autoregression model. Results show an inverse relationship between GDP and CO2 emissions in low-growth economies, and a positive correlation in moderate and high-growth economies. Additionally, more evidence can found in the study of Li and Chen (2024). Study disclosed that, trade openness exacerbates species loss, with higher levels of loss exacerbated by increased openness. Another evidence found in the study of Kaukab and Anggara (2024). Study discloses that, trade openness is positively associated with inflation in the long run, while GDP and FDI have negative effects. More evidence found in the study of Xu et al. (2023). This Study disclose that, while growth in renewable energy and trade openness worsen the environment, institutional quality and renewable energy use promote green finance development. Further evidence found in the study of Ozkan et al. (2023). Study discloses that, green technological innovation and financial development positively impacted carbon efficiency in China.

One of the authors of the study is Khalid Mahmood Zaffar. The study examines the impact of trade openness and budget deficits on Pakistan's public debt from 1975 to 2020. This paper uses ARDL model. Results show that variables like public debt, budget deficit, trade openness, and inflation have long- and short-term co-integration.

The study of Wang et al. (2023a) which investigate the impact of natural resources, institutional quality, trade openness, and foreign direct investment on economic development in 10 European nations between 2008 and 2020 by employing GMM model uses these factors to analyze economic recovery, natural resources, and sustainable and nonrenewable energy consumption. Results show that countries' economies improve after switching to renewable and nonrenewable energy sources. Additionally, more evidence can found in the study of Wang et al. (2023b). Study finds that, weak decoupling, with two breakpoints. Another evidence found in the study of Dam and Sarkodie (2023). Study disclose that, real income, renewable energy consumption, and trade openness are key indicators of environmental sustainability in Turkiye. More evidence found in the study of Adebayo et al. (2022). Study shows that, geopolitical risk increases and decreases carbon emissions, while non-renewable energy consumption, economic growth, and trade openness hinder environmental quality. Additionally, more evidence can found in the study of Wang et al. (2023c). Study finds that, industrialization positively influences renewable energy intensity, while trade openness negatively affects it. Further evidence found in the study of Voumik et al. (2023). Study figure out that, cointegration, with economic growth positively impacting energy usage in the long-run and short-run.

The study of Wenlong et al. (2023) which investigate the impact of factors like energy efficiency, technology innovations, trade openness, and institutional quality on environmental quality in 10 Asian economies from 1995-2018 by employing CS-ARDL model. Findings show trade openness and institutional quality negatively affect environmental quality, while energy efficiency and technology innovations positively impact it. Additionally, more evidence can found in the study of Haseeb et al. (2023) which disclose that, human capital is negatively related to carbon dioxide emissions. Another evidence found in the study of Wang et al. (2024b). Study discloses that, when trade openness is taken as a threshold variable, the negative regression coefficient of ICT and carbon emissions decreases, then increases in low-income groups. More evidence found in the study of Pata et al. (2023b). Study disclosed that, renewable energy improves the LCF in the short and long run, while trade openness stimulates it in the long run. Another evidence can found in the study of Akhayere et al. (2023). Study discloses that, primary energy use, trade openness, and financial development negatively impact the LCF, damaging environmental quality.

The study of Pata et al. (2023a) which investigate the impact of renewable energy, tourism, foreign direct investment, and income on environmental degradation in six ASEAN countries from 1995 to 2018 by employing ARDL model. Results show that tourism and foreign direct investment increase CO_2 emissions, while real income and trade openness reduce it. Additionally, more evidence can found in the study of Chhabra et al. (2023). Study discloses that, trade openness causes environmental degradation, while institutional quality contributes positively to sustainability through reduced corruption, improved political stability, and better law and order. Another evidence found in the study of Wu (2022). Study finds that, trade openness and green finance levels are significantly influenced by natural resource use. More evidence found in the study of Huang and Liu (2022). Study shows that, trade openness inhibits green productivity, but increasing regulations can alleviate its negative effects. Furthermore evidence found in the study of Can et al. (2022). Study discloses that, green products reduce a country's ecological footprint, providing crucial information for sustainable development and future research.

2.1.3 Institutional quality effects on green growth

The study of Alsagr and Ozturk (2024) which investigate the impact of resource rent and institutional quality on green investment in 51 top green investing countries from 1996 to 2021 by employing 2SLS model. Results show that resource rent negatively impacts green investment, while political stability, government effectiveness, corruption control, rule of law, and regulatory quality boost it. Additionally, more evidence can found in the study Sethi et al. (2024). Study discloses that green finance, technology innovation, and institutional quality increase CO2 emissions, while agricultural value-added and renewable energy use have negative effects. Another evidence found in the study of Wahab et al. (2024). Study discloses that, a strong correlation between economic expansion and greenhouse gas emissions, emphasizing the need for sustainable growth strategies. More evidence found in the study of Zaman and Yu (2024). Study figures out, the effects of infrastructure development, economic growth, foreign direct investment, technological innovation, and institutional quality on CO2 emissions found that foreign direct investment and institutional quality improve environmental quality. Furthermore evidence found in the study of Akhtar et al. (2024). Study discloses that, after controlling for technological innovation, foreign direct investment, population, economic globalization, and GDP per capita, significantly promote sustainable energy in the long run.

The study of Zheng et al. (2024) which investigates the link between higher education, institutional quality, and CO2 emissions in E-7 economies using data from 1995 to 2020. Findings show that better education and improved institutions significantly decrease emissions, particularly in stronger institutions. Another study of Appiah et al. (2022) which investigate the relationship between institutional quality (IQ) and carbon emissions in Sub-Saharan African countries between 1996 and 2019 by employing Environmental Kuznets Curve (EKC) hypothesis. Results show that economic growth initially worsens the environment, but further expansion improves it. Additionally, more evidence can found in the study Abudaqa and Ab-Samat (2024). Study discloses that, renewable energy, ecological innovations, institutional quality, and economic growth are significant in reducing carbon emissions, while non-renewable energy sources and economic growth contribute more. More evidence found in the study of Qayyum et al. (2024). Study discloses that, that IQ and ICT protect the atmosphere, reduce ecological impact, and slow down pollution. Another evidence found in the study of Abbas et al. (2024). Study discloses that, TFP is positively associated with CE, while institutional quality negatively impacts CE.

The study of Guan et al. (2024) which investigate the relationship between environmental and social capital in BRICS economies from 1996 to 2021 by employing NARDL model. It reveals that social capital, institutional quality, income, and renewable energy consumption are linked to sustainability levels. Additionally, more evidence can found in the study Ansari et al. (2024). Study discloses that, financial inclusion and digital finance can help developing countries achieve environmental sustainability, with renewable energy sources playing a crucial role in reducing carbon emissions. More evidence found in the study of Aydin et al. (2024). Study discloses that, environmental technologies improve Austria's environmental quality, while globalization reduces it. Another evidence found in the study of Uddin et al. (2024). Study disclosed that, institutional quality, financial development, and health expenditure contribute to longer life expectancy, while carbon emissions, ecological footprint, birth rate, mortality rate, and population growth reduce it.

The study of Guo et al. (2024) which investigate the health impacts of greenhouse gases, energy use, institutional quality, and globalization on 23 developing economies. Using panel data from 2000-2022, the study uses estimation techniques and panel causality tests by employing GMM and PARDL model. Results show a positive association between health and its lag value, with institutional quality negatively influencing health expenditure. Furthermore evidence can found in the study of Cui et al. (2024). Study disclosed that, these factors, along with foreign direct investment, reduce CO2 emissions, but they also increase environmental degradation. Another evidence can found in the study of Karim et al. (2024). Study figures out that, remittances positively affect the financial sector and institutional quality, while the financial sector enhances economic growth. More evidence can found in the study of Wang et al. (2023d). Study found that, improving institutional quality could help eliminate resource curse on green economic growth. Also, found that high-income countries saw increased promotion effects of natural resource abundance when institutional quality was above the threshold value, while low- and middle-income countries saw natural resource curse as a blessing only when it was above certain thresholds. Another evidence can found in the study of Obobisa et al. (2023). Study discloses that, green innovation mitigates CO2 emissions, while institutional quality increases them.

The study of Amin et al. (2023) which investigates the long-run effects of institutional quality, green technology innovation, renewable energy, trade openness, population, and economic growth on CO2 emissions in South Asian countries from 1995 to 2020. Results show that green technological innovation and renewable energy reduce emissions by 0.084% and 0.054%, respectively. Another evidence can found in the study of Çitil et al. (2023) which investigate the impact of green investments, institutional quality, and political stability on air quality in G-20 countries from 2004-2020 by employing CADF and MMQR model. Results show that green finance investments, institutional quality, and political stability increase air quality, while total output and energy consumption decrease it. Further evidence can found in the study of Hunjra et al. (2023). Study discloses that, positive relationship between institutional quality and economic sustainability, but a negative relationship with CO2 emissions and deforestation. Additionally, more evidence can found in the study of Vatamanu and Zugravu (2023). Study found that, increased financial development positively impacts renewable energy consumption. More evidence can be found in the study of Jahanger et al. (2023). Study discloses that, natural resources, globalization, institutional quality, and human capital negatively affect carbon dioxide emissions, while foreign investment and energy utilization can increase emissions.

The study of Rehman et al. (2023). Study investigate the impact of ICT, institutional quality, economic growth, and energy consumption on the ecological footprint in ASEAN countries from 1990-2018. Results show that ICT and institutional quality mitigate environmental degradation, while economic growth and energy consumption increase it by employing EKC. Further study can found in the study of Shahbaz et al. (2023). Study disclose that, show that informality has a positive long-term impact in European countries, while negative in Asian countries. Another evidence can found in the study of Farooq et al. (2023). Study found that, public debt significantly degrades environment quality in low and overall OIC-income countries, but mends it in high-income countries. More evidence can found in the study of Sibanda et al. (2023). Study discloses that, natural resource rents and institutional quality from 1994 to 2020 found a positive link between natural rents and degradation. Additionally evidence can found in the study of Li et al. (2023). Study discloses that, financial technologies and digitalization reduce dependency on natural resources, while human development and institutional quality lead to lower dependency. Another evidence can found in the study of Kwakwa (2023). Study suggests that, urbanization and trade openness increase emissions, while income positively affects them.

2.2 Research question

Depending on your research topic, aim and assigned variables you can find some research questions below, based on how natural resource rent, trade openness and institutional quality affect green growth.

1. How does green growth effectively balance economic development with environmental protection while maintaining social inclusion across different economies?

The question addresses how green growth effectively balances economic development with environmental protection by promoting efficient resource use, renewable energy adoption, and sustainable technologies. It aims to stimulate economic growth while minimizing environmental harm, ensuring that social inclusion is prioritized by addressing inequality and providing access to basic services. Across different economies, green growth strategies are tailored to local contexts, leveraging policy frameworks, innovation, and institutional support to foster sustainable and equitable development.

2. To what extent can clean and efficient use of natural and energy resources meet basic human needs without compromising environmental sustainability?

The research analyzes how clean and efficient use of natural and energy resources can meet basic human needs such as food, water, and shelter while minimizing environmental impact by optimizing resource management and reducing waste. Through innovations like renewable energy, sustainable agriculture, and circular economies, it is possible to provide for human needs without depleting natural resources or harming ecosystems, ensuring long-term environmental sustainability. However, the extent to which this is achievable depends on the adoption of appropriate technologies, policies, and global cooperation.

3. What are the specific roles and impacts of technological innovation, government policies, and institutional quality in successfully implementing green growth strategies across different economic contexts?

Technological innovation drives green growth by providing cleaner, more efficient solutions for energy use, waste management, and resource conservation. Government policies shape the framework for green growth, setting regulations, incentives, and guidelines that encourage sustainable practices. Institutional quality ensures that these policies are effectively implemented and that the necessary infrastructure and governance are in place to support green growth. Together, these factors influence the success of green growth strategies across different economies by aligning technological advances with strong policy support and effective institutions tailored to local economic and environmental contexts.

2.3 Hypothesis development

As I have 3 research questions/objectives, I will have 3 corresponding hypotheses:

Hypothesis 1 (H1): Green growth strategies positively drive economic development while ensuring environmental protection and social inclusion, enabling countries to expand economically without causing significant ecological harm.

Hypothesis 2 (H2): The efficient use of natural and energy resources through clean technologies and sustainable practices helps meet basic human needs while preserving environmental sustainability, demonstrating that resource management can achieve both development and ecological goals simultaneously.

Hypothesis 3 (H3): Technological innovation, government policies, and institutional quality work together to successfully implement green growth strategies, with innovation improving environmental outcomes, strong institutions enhancing policy effectiveness, and supportive policies boosting the adoption of sustainable practices and clean technologies.

Table 1: Summary of Literature Review

Author	**Country (period)**	**methodology**	**Variables**	**Findings**	**Casualty**
Zhang et al. (2022)	ecological footprint in China data from 2000 to 2018	NARDL	ECFP, GINV, GRTI, NARR, EGDP	(+ve) relationship between these factors and ecological footprint	no
Chau et al. (2022)	(G7) countries between 2001 and 2019	MMQR	NRR, REP, REC, CRW, EG, PG	Green energy exploration and consumption (+ve) impact the sustainability of natural resources in G7 countries	no
Alsagr and Ozturk (2024)	51 top green investing countries from 1996 to 2021	2SLS	REI, ETI	resource rent (-ve) impacts green investment	no
Liang et al. (2024)	trade for developing countries from 2000 to 2019	FMOLS, DOLS	LLC, IPS	(+ve) association between natural resource rent and green financing	no
Cheng et al. (2020)	30 provinces in China from 2003 to 2016	ML index	TFP, GTFP	abundant natural resources lower green total factor productivity, and resource industry dependence inhibits growth	no
Li et al. (2022)	Asymatric derivers of Ecological footprint (EF) is explored in ARCTIC region.	FMOLS, DOLS, MMQR	NRR, EFP, GI, GDP	Economic growth and natural resource rent (+ve) impact ecological footprints, while green innovation promotes sustainability.	no

Khan et al. (2020)	between 1984 and 2018 (Pakistan)	ARDL, NARDL	NRR, FD, IQ	natural resource rent (-ve) impacts financial development, while institutional quality (+ve) development and moderates the relationship	no
Fu and Liu (2023)	global data over the last three decades (1990–2020)	DOLS, FMOLS, CCR	GDP, EP, DERTI	natural resources influence sustainable development, with mineral rents and natural gas rents (+ve) affecting and forest rents negatively	yes
Khaddage-Soboh et al. (2023)	G-7 countries from 1990 to 2020	MMQR	CO2E, REC, GDP, Env_Tax, Env_Reg, NRR	(-ve) association between natural resource rents and CO2 emissions, but a (+ve) relationship at higher quantiles	no
Huang et al. (2023)	USA from 1995-2015	QARDL	CO2EM, CO2, FD, NRR, URB	higher financial development, urbanization, and natural resources increase environmental pressure on the economy	no
Zhou et al. (2024)	(BRICS) from 1994 to 2018	TFP	TFP, REC, EF, CO2, NRR, InGDP	total factor productivity and renewable energy consumption improve environmental quality, but economic growth and natural resource rents are detrimental	no
Shahid et al. (2024)	China from 1990 to 2020	ARDL	GTFEP, EOU, ER, RNR, GI	All the determinants are found to effect GTFEP (+ve)	yes

Chen et al. (2023)	E-7 from 1992-2020	MMQR	IQ, NR, RE, EP, GDP, CO2E	institutional quality mitigates CO2 emissions by combating corruption and upholding the rule of law	no
Mumuni and Mwimba (2023)	24 African countries from 1990 to 2020	ARDL, FGLS	CO2E, InGDP, REC, FEC, GFCF, INFL	green energy consumption has both short-term and long-term growth-limiting effects, while CO2 emissions have (+ve) impacts	no
Li et al. (2024a)	Russia's economic growth from 2000-2022	ADF	GPR, NRR	GPR (+ve) impacts economic growth, while green finance and commerce boost growth across all quantiles	yes
Appiah et al. (2022)	G7 economies	AGM, QR, FMOLS, DOLS	NRR, REC, FFEC, CP2E	(+ve) relationship between total natural resources rent and pollution, with renewable energy consumption (-ve) affecting the environment	yes
Tachega et al. (2024)	Africa from 2010 to 2018	SMB-DEA, PMG ARDL	CP2E, GNIPC	traditional and renewable energy efficiency are low, and economic expansion has significant environmental costs	no
Huang and Guo (2022)	30 Chinese provinces from 1995 to 2017	ARDL	NRR, TI, RI, CO2E	(+ve) correlation between these factors, financial development contributing to carbon emissions in the long term	no

Nguyen et al. (2024)	economies from 2002 to 2022	AGM	EPI, FDI, RED, GTI, NRR, NCAP	regional development, green innovation, natural capital, and natural resource rent (+ve) contribute to environmental performance, while FDI has a (-ve) effect	no
Ramzan et al. (2018)	from 1970 to 2017 (Pakistan and india)	ADF	GDP, TNR, PAK, B	(+ve) and significant effect of total natural resources on GDP per capita, with two co-integrated equations	no
Debonheur et al. (2024)	41 African countries from 1996-2019	GMM	NRR, ED, ID, EP	total rents (-ve) affect development, but food imports mitigate this	no
Öztürk et al. (2023)	G7 economies from 1997-2019	PVAR	GDPPC, CO2, REN	unidirectional causal relationship between GDPPC, CO2 and REN, with no significant relation between CO2 and REN	yes
Ngo (2024)	Vietnam from 2003 to 2022	OLS, FGLS, GMM	GTFP, NRP	resource curse phenomenon and how abundance helps achieve the Sustainable Development Goals through green production methods	no
Shen et al. (2021)	30 provinces of China from 1995 to 2017	CS ARDL	CO2, NRR	(+ve) effects of energy consumption and financial development on carbon emissions, while green investment is (-ve) linked to CO2	no

Ma (2024)	China's economy from 2012-2022	PGDP	GRI	show globalization (-ve) impacts regional emissions, but economic development and green finance (+ve) correlate with CO2 emissions	no
Chen and Chen (2024)	China for the period of 1990–2022	ARDL	CO2, NRR	natural resources increase (+ve) emissions, while digital finance reduces (-ve) them	no
Zhang et al. (2024b)	BRICS economies from 2016 to 2023	CS-ARDL, NARDL	CRE, NRR, EPI, FTech	fintech and NRR improve economic recovery but harm environmental quality	no
Akadiri et al. (2023)	Nigeria from 1970 to 2020	BCSGC, WC	FG, NNR	policymakers should consider these factors when formulating environmental policies to mitigate climate change effects	yes
Wang et al. (2024c)	96 developing countries from 2000-2018	LCF	EF, CO2	TRA impacts environmental quality; higher resource rents enhance ecology, while corruption hinders pollution control.	no
Wang et al. (2024a)	South Asian countries from 1990 to 2021	DF-GLS, Phillip perron	CO2, RELO, REDEV, GOVEEXP, FD	Financial development and education harm environment; resources, renewables, and R&D lower emissions	no
Ma et al. (2024a)	top and least green growth economies	MMQR	RE, EFP	(-ve) between ecological footprint renewable energy, technological change,	no

	spanning from 1990 to 2021			ecological policies, and taxes	
Okolo et al. (2024)	79 economies from 1995 to 2021	IVFE	NRR	rents, including oil and natural gas, significantly promote (+ve) innovation	no
Udemba et al. (2024)	Norway, 1970 to 2018	ARDL	FDI, CO2, FF	(+ve) between fuels and carbon emissions, while economic growth and natural resources improve the environment	yes
Hacıimamoğlu and Cengiz (2024)	period between 1990 and 2018	MMQR	REC, NRR	REC and NRRs reduce environmental degradation	no
Jin and Zafar (2024)	emerging economies from 1990 to 2021	QR (Quantile Regression)	NRD, HC, EG, GER, FF	Natural resource depletion and human capital aid green energy transition; financial development hinders it.	no
Appiah et al. (2024)	OECD countries from 1990 to 2021	AMG, CCEMG	NR	innovation decreases extraction, while FDI expands it. innovation independently increases extraction	yes
Luo et al. (2023)	Asian countries from 1990 to 2018		NRC, CO2	strong (+ve) between natural resource rents and carbon emissions, especially in low-income countries	no
Tariq et al. (2024)	emerging economies over the period 1996–2021	standard green Solow growth (SGSG)	GTO, GG, CO2	(+ve) shocks in these factors mitigate carbon emissions and promote green economic growth	no

Qing et al. (2024)	OECD countries	AGM, DH, GET	GEC, ED, TLP, EDT, TP, OP	environmental degradation (-ve) impacts GEC, while oil prices and economic development (+ve) affect it	no
Wang et al. (2024d)	OECD and G20 countries between 1997 and 2019		CO_2	trade openness increases emissions, while trade diversification reduces them	no
Ibrahim et al. (2022)	time series data from 1990 to 2020	ARDL	RE	Renewable energy and technology mitigate emissions through long-run cointegration effects.	no
Ghazouani and Maktouf (2024)	oil-exporting nations for the period 1971–2014	PADL	CO_2	bidirectional link with natural resources, economic growth, and CO_2 emissions, and a unidirectional link with trade openness and CO_2 emissions	Yes
Wang et al. (2024e)	69 countries from 1993 to 2019	STIRPAT	AI, CO_2	AI aids energy transition and lowers carbon emissions, facilitated by trade openness.	no
Afjal and Devi (2024)	OECD countries from 1995 to 2020	panel vector autoregression	GDP, CO_2	Low-growth economies show GDP-CO_2 inverse relationship; high-growth economies show (+ve) correlation.	yes
Li and Chen (2024)	27 the B&R countries from 2006 to 2015		EF	trade openness exacerbates species loss, with higher levels of loss exacerbated by increased openness	no

Khalid Mahmood Zaffar	Pakistan's public debt from 1975 to 2020	ARDL	PD, BD, TO, Inflation	variables like public debt, budget deficit, trade openness, and inflation have long- and short-term co-integration	no
Kaukab and Anggara (2024)	period from 1985 to 2022	ARDL	GDP, FDI	trade openness is (+ve) link with inflation in the long run, while GDP and FDI have (-ve) effects	no
Xu et al. (2023)	Asian countries from 1990 and 2019	ARDL	GDP, RE, TO, IQ, GF	Renewable energy growth and trade openness harm the environment; institutional quality fosters green finance development.	no
Ozkan et al. (2023)	China from 1990 to 2018	DARDLS	CAE, GTI, FD, TO	green technological innovation and financial development (+ve) impacted carbon efficiency in China	no
Wang et al. (2023a)	10 European nations between 2008 and 2020	GMM	NRR, IQ, TO, FDI	countries' economies improve after switching to renewable and nonrenewable energy sources	no
Wang et al. (2023b)	124 countries around the world from 2000 to 2018	Tapio decoupling and structural threshold	TO, CO2	Trade openness, economic growth, and carbon emissions show weak decoupling relationships.	no
Dam and Sarkodie (2023)	period from 1965 to 2018(Turkiye)	ARDL	GDP, REC, TO	Real income, renewable energy, and trade openness are vital for Turkiye's sustainability.	yes

Adebayo et al. (2022)	from 1985Q1 to 2019Q4(India)	QQR	CO2, NRE, TO, EG	Geopolitical risk affects carbon emissions; non-renewable energy and economic growth harm environmental quality.	no
Wang et al. (2023c)	China from 1986 to 2020	Path model	GDP, REI	industrialization (+ve) influences renewable energy intensity, while trade openness (-ve) affects it	no
Voumik et al. (2023)	Australia from 1972 to 2021	ARDL	ENER, GDP, FDI, URBA, TO	economic growth (+ve) impacting energy usage in the long-run and short-run	no
Wenlong et al. (2023)	10 Asian economies from 1995-2018	CS-ARDL	TO, IQ, TI, EE	trade openness and institutional quality (-ve) affect environmental quality, energy efficiency and technology innovations (+ve) impact it	no
Haseeb et al. (2023)	BRICS countries from 1998 to 2018	Driscoll–Kraay standard errors and the Dumitrescu–Hurlin causality	HC, CO2	that human capital is (-ve) related to carbon dioxide emissions	no
Wang et al. (2024b)	92 countries from 2006 to 2017	LLC, IPS, Fisher-ADF, Fisher-PP	FD, TO, ICT, CO2	Trade openness affects ICT's impact on carbon emissions, showing varied effects in low-income groups.	no
Pata et al. (2023b)	LAC countries data from 1990 to 2018	PGM-ARDL	LCF, KOF, EG, REN, TO	Renewable energy enhances LCF short-term and long-term; trade	no

				openness boosts it long-term.	
Akhayere et al. (2023)	Turkey's load capacity factor (LCF) between 1965 and 2018	QC, QQR, NQR, QR	TO, FD, EQ	Energy use, trade openness, and financial development harm environmental quality (-ve).	yes
Pata et al. (2023a)	six ASEAN countries from 1995 to 2018	ARDL	CO2, RI, TO, RE	Tourism and foreign investment raise CO2 emissions; income and trade reduce emissions.	no
Chhabra et al. (2023)	BRICS countries from 1991 to 2019	DCCE	IQ, RE, NRS	Trade openness harms the environment; strong institutions enhance sustainability by reducing corruption and improving stability	no
Wu (2022)	from 1981 to 2020 of China	VAR	TO, GF, NR	Coal and oil use (-ve) impact green finance, while gas consumption predicts trade openness	no
Huang and Liu (2022)	110 cities from 2006-2018		TO	Trade openness hinders green productivity; regulations can mitigate impacts.	no
Can et al. (2022)	31 OECD countries from 2007-2017	EKC	Green products	The Kuznets curve suggests green products lower ecological footprints, aiding sustainable development and future research.	no

Alsagr and Ozturk (2024)	51 top green investing countries from 1996 to 2021	2SLS	GDP, CO2, TO, REI, ETI, FDI	resource rent (-ve) impacts green investment, political stability and effective governance enhance it significantly	no
Sethi et al. (2024)	25 developing countries from 1998 to 2019	Driscoll-Kraay and two-step SGMM	GF, GTI, IQ, RE, CO2	Green finance and tech innovation raise CO2 emissions; agriculture and renewables reduce them negatively	no
Wahab et al. (2024)	OECD countries, period from 1990 to 2022	MMQR	GHG, EG, G, NRR, REO, IQ	Economic growth correlates with greenhouse gas emissions, highlighting sustainable strategies' necessity	no
Zaman and Yu (2024)	G7 countries. Using annual panel data from 1996 to 2020	CS-ARDL	IQ, EG, FDI, TI, IQ	Infrastructure, economic growth, foreign investment, technology, and institutions influence CO2 emissions and environmental quality.	no
Akhtar et al. (2024)	top 14 green economies from 1990 to 2022	PMG-ARDL, CS-ARDL	TI, FDI, P, EG, GDP, IQ	Technological innovation, investment, population, globalization, and GDP enhance sustainable energy through policy and institutional quality	no
Zheng et al. (2024)	E-7 economies using data from 1995 to 2020		R&D, REC, GDP	Better education and strong institutions reduce emissions significantly	no
Appiah et al. (2022)	Sub-Saharan African countries	EKC	IQ, CO2	economic growth initially worsens the environment,	yes

	between 1996 and 2019			but further expansion improves it	
Abudaqa and Ab-Samat (2024)	United Arab Emirates (UAE) from 1995-2020	ARDL	RE, EI, IQ, EG	Renewable energy and innovations reduce carbon emissions; non-renewable energy and growth increase them significantly	yes
Qayyum et al. (2024)	Southern Common Market (MERCOSUR) economies from 1990-2021	EKC, CSD, CS-ARDL	EF, GDP, EC, TOP, ICT, IQ	IQ and ICT protect the atmosphere, reduce ecological impact, and slow down pollution	no
Abbas et al. (2024)	BRICS countries from 1996 to 2022	CS-ARDL	TFP, IQ	TFP is (+ve) with CE, while institutional quality (-ve) impacts CE	yes
Guan et al. (2024)	BRICS economies from 1996 to 2021	NARDL	REC, SC, LAO, GS, PS, GDP	Social capital, institutional quality, income, and renewable energy impact sustainability levels	no
Ansari et al. (2024)	data from 2004 to 2021(Pakistan)	ARDL	CO2, DF, FINC, INSQ, RE	Financial inclusion and digital finance aid developing countries' environmental sustainability through renewable energy and reduced emissions	no
Aydin et al. (2024)	ten European countries that invest in the highest environmental technology from 1990 to 2019	LCC	G, ET, EG, IQ	European Union's carbon zero target and the results of achieving carbon neutrality by 2030	no

Uddin et al. (2024)	Asian countries from 2002 to 2020	CS-ARDL, FMOLS, DOLS	FD, IQ, HE	Institutional quality, financial development, and health spending increase life expectancy; other factors decrease it	no
Guo et al. (2024)	23 developing economies data from 2000-2022	GMM, PARDL	IQ, TO, GTI, EG, PG, REC	(+ve) link between health and its lag value, with institutional quality (-ve) influencing health expenditure	yes
Cui et al. (2024)	BRICS countries from 1992 to 2021	CS-ARDL, FMOLS, DOLS	IQ, EP, FDI	Geopolitical risk and economic policy uncertainty affect institutional quality and energy productivity significantly	no
Karim et al. (2024)	68 developing economies from 2000 to 2018	GMM	IQ, CO2	Remittances (+ve) affect the financial sector and institutional quality, while the financial sector enhances economic growth	no
Wang et al. (2023d)	48 BRI Countries	SBM, GML	IQ	High-income countries benefit from resource abundance with good institutional quality; low/middle-income countries need thresholds to avoid resource curse.	no
Obobisa et al. (2023)	African countries from 1990 to 2016	CADF, CIPS	IQ, EC	green innovation mitigates CO2 emissions, while institutional quality increases them	yes

Amin et al. (2023)	South Asian countries from 1995 to 2020		IQ, TO, GTI, EG, PEG, RE	that green technological innovation and renewable energy reduce emissions by 0.084% and 0.054%,	yes
Çitil et al. (2023)	G-20 countries from 2004-2020	CADF, MMQR	GFI, IQ, PS, EC	green finance investments, institutional quality, and political stability increase air quality, while total output and energy consumption decrease it	yes
Hunjra et al. (2023)	65 developing economies from 1984 to 2019	DWH	IQ, CO2	(+ve) link between institutional quality and economic sustainability, (-ve) relationship with CO2 emissions and deforestation	no
Vatamanu and Zugravu (2023)	27 EU member states over the 2000–2020	quantitative techniques and qualitative sequential methodology	FD, IQ, REC	increased financial development (+ve) impacts renewable energy consumption	no
Jahanger et al. (2023)	73 developing nations from 1990-2018		NRR, IQ, G, HC, FDI	natural resources, globalization, institutional quality, and human capital (-ve) affect carbon dioxide emissions, while foreign investment and energy utilization can increase emissions	no
Rehman et al. (2023)	ASEAN countries from 1990-2018	EKC	ICT, IQ	ICT and institutional quality mitigate environmental degradation, while	no

				economic growth and energy consumption increase it	
Shahbaz et al. (2023)	Europe and Asia from 2002 to 2018	PMG-ARDL	REN, RL, CC, GE	(+ve) long-term impact in European countries, while (-ve) in Asian countries	no
Farooq et al. (2023)	OIC economies from 1996 to 2018		IQ	public debt significantly degrades environment quality in low and overall OIC-income countries, but mends it in high-income countries	no
Sibanda et al. (2023)	sub-Saharan African countries from 1994 to 2020	GMM	GDP, FPC, TO, FDI, GVE, ACTE, FDIP	(+ve) link between natural rents and degradation	no
Li et al. (2023)	OECD economies from 2002-2020	MMQR, FMOLS	IQ, FT, Digi	Financial technologies and digitalization decrease resource dependency; human development and institutional quality further reduce it	no
Kwakwa (2023)	32 countries from 2002-2021	FMOLS	RE, IQ	urbanization and trade openness increase emissions, while income (+ve) affects them	no

Chapter 3: Data and Methodology of the study

3.1 Theoretical development of the study

The study of Hickel and Kallis (2020) found that, Green growth has steadily gained greater recognition as one of the main ways to achieve 21st-century sustainable development. Focusing on efficient natural resource usage, decreasing environmental impacts, and boosting clean technology, it is conceived to balance economic development with social inclusion and environmental sustainability. These interrelated functions of trade openness, institutional quality, and natural resource rent are three important factors that can be analyzed in order to understand the dynamics of green growth. Besides its direct impact on green growth, these independent factors interact in a complex manner with each other to generate different outcomes under diverse geographic and economic conditions.

Another study of Li et al. (2024b) investigate that, The financial benefits gained by the use of natural resources are represented as natural resource rent. It has a complex effect on green growth. On the one hand, resource rents have the potential to supply crucial funds for investments in sustainability-promoting technology and environmental projects. However, excessive dependence on natural resources can result in the "resource curse," a paradox whereby a shortage of natural resources promotes unsustainable practices and hampers institutional growth. Efforts to create green growth are hampered by this issue, which frequently shows up as insufficient regulatory frameworks, corruption, and poor governance. As a result, resource rent distribution and management are crucial. The best-positioned nations to use these rents for green growth are those that reinvest resource profits into environmentally friendly initiatives and technical development. Norway and other countries with robust institutional structures have effectively used oil royalties to finance environmental conservation and renewable energy initiatives. The need for strong governance systems is highlighted by the possibility of environmental damage and economic decline in resource-rich but institutionally weak nations.

Another study of Qamruzzaman et al. (2024) figure out that, Another factor that affects green growth is trade openness, which has two effects. Trade openness makes it easier for people to trade goods, services, and technologies. Using cleaner production methods could make trade more environmentally friendly. This result of trade is sometimes called the "technology transfer" effect. Concerns have been raised about the pollution haven theory, which says that when trade is opened up, polluting industries may move to places with less strict environmental laws, which could hurt the environment in developing countries. Three things determine the net effect of trade access on green growth: size, make-up, and technology. The pressures on the environment that come from more production and usage because of trade are called scale effects. Composition effects are changes in the structure of an industry, which can help cleaner or more polluting industries based on which ones are better at making things. The effects of technology show how advanced technologies can help lessen the damage they do to the world. To give you an example, trade deals that include environmental standards can push countries to change their ways and support green growth goals.

The study of Teklie and Yağmur (2024) investigate that, The quality of institutions is a key factor in determining green growth because it affects how well resource management, trade policies, and environmental laws work. Strong organizations protect the environment by reducing down on corruption, keeping the government stable, and making sure that government workers are held accountable. These traits make it possible to make and follow through on effective environmental rules, the fair distribution of natural resource rents, and policies for sustainable development. Governance problems happen a lot when there aren't strong institutions in place, which hurts attempts to achieve green growth. Countries with good institutions are better able to use trade freedom to help the environment while minimizing the bad effects it might have. It's also possible for the quality of institutions to change the relationship between trade openness and environmental results. For example, countries with strong government systems are more likely to make sure that trade deregulation leads to the use of green technologies instead of harming the environment.

The study of Zhao et al. (2023) finds that, When combined, natural resource rent, trade openness, and institution quality impact sustainability results. Institutional quality ensures environmental compliance and promotes green corporate practices, reducing the environmental impact of trade openness. How well natural resource rents are used depends on how strong the organizations that spend and invest resource money are. Trade openness promotes openness and responsibility through global standards and unity, which can boost institutions.

Economic and geographic factors also affect how these components interact. Institutional quality is frequently the most critical factor in green growth in developing economies. Governance needs to improve since weak institutions in these areas can worsen the negative effects of natural resources and free trade. In mature economies with stronger institutions, trade openness and sustainable growth are more related. These nations can better access foreign technologies and enforce environmental laws. BRICS countries Brazil, Russia, India, China, and South Africa have distinct dynamics due to their large GDP contributions and environmental issues. Their experiences show the importance of creating area- and economy-specific green growth strategies.

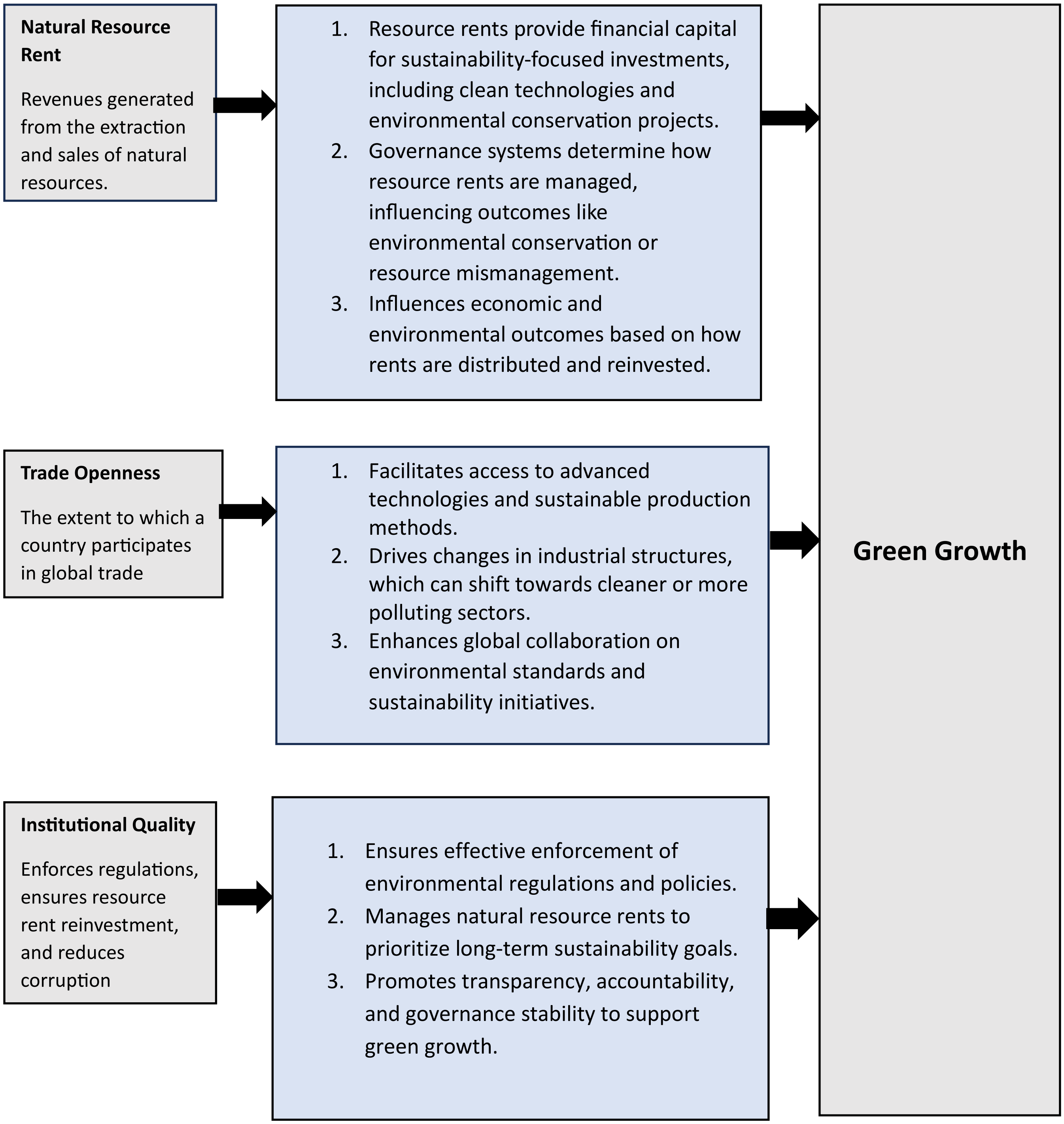

Figure 1: Mechanism Analysis

3.2 Variables definition

3.2.1 Concept of natural resource rent (NRR)

The study of Moses and Brigham (2024), Simionescu et al. (2024), Simionescu et al. (2024), Yu et al. (2024) and Pratibha et al. (2024) investigate that, Natural resource rent refers to the economic value derived from the extraction and utilization of natural resources, including land, minerals, and forests. It encompasses three types of rents: differential rent (associated with resource quality), regulatory rent (arising from governance and societal regulations), and locational rent (linked to geographic advantages). These rents, collectively termed as the "Natural Dividend," represent windfalls generated by managing commonly held resources and can be taxed without distorting investments. While natural resource rents can positively contribute to sustainable development through effective management and investment in green growth initiatives, they also pose challenges. In China, they have been linked to sustainable economic progress, provided governance frameworks like transparency and the rule of law are robust. Conversely, in Nigeria, resource rents have exacerbated environmental degradation, emphasizing the need for channeling revenues toward eco-friendly investments. Similarly, in India, asymmetric shocks in resource rents have affected public debt, highlighting the risks of over-reliance on natural resource income. Efficient use of natural resource rents requires prudent governance, sustainable policies, and investments in renewable technologies to mitigate environmental risks, stabilize economies, and promote long-term resilience. These insights underscore the dual-edged role of resource rents in fostering or impeding sustainable development.

3.2.2 Proxy of natural resource rent

Study of van Krevel and Peters (2024), Sawadogo and Ouoba (2024), Akadiri et al. (2024), Dao et al. (2024), and Akram et al. (2024) investigate that Natural resource rent indicators provide crucial insights into a country's economic sustainability and resource management. Key indicators include resource rent as a percentage of GDP, which reflects the relative importance of natural resources in the economy. Sectoral rent contributions offer disaggregated data on rents from various sectors like oil, gas, minerals, and forests. The genuine savings rate adjusts national savings by accounting for natural resource depletion, providing a more accurate measure of long-term economic sustainability. Resource exports as a share of total exports highlight a country's dependence on natural resource exports, potentially indicating increased economic volatility. Government resource revenues measure the effectiveness of fiscal policies in capturing resource rents for public benefit. Total natural resource rents as a percentage of GDP encompass all rents generated by natural resources. The natural resource depletion rate shows the pace at which resources are being consumed. Lastly, the resource governance index assesses the quality of resource management practices. These indicators, when analyzed collectively, offer valuable insights into a country's resource management practices and their impact on sustainable economic development.

3.2.3 Anticipate relationship

The study of Zhang et al. (2022), Nguyen et al. (2024), Liang et al. (2024), Okolo et al. (2024), Alsagr and Ozturk (2024), Cheng et al. (2020), Khan et al. (2020) and Ma et al. (2024a) investigate that, The relationship between green growth and natural resource rents (NRR). Positive impacts include green financing, sustainability, and innovation, as evidenced in China regional development, where NRR enhances environmental performance. Similarly, Liang et al. (2024) highlighted a link between NRR and green financing in developing countries, while Okolo et al. (2024) observed innovation promotion in 79 economies. Conversely, negative effects emerge in contexts like Alsagr and Ozturk (2024) on green investing nations, where NRR negatively impacts green investments, and in China, showing a decline in green productivity. Additionally, adverse financial development impacts in Pakistan, and Ma et al. (2024a) linked resource rents to diminished ecological footprints in green economies. These findings suggest that while NRR can bolster growth and financing, weak institutional frameworks or mismanagement may obstruct sustainability and green development efforts.

3.2.4 Concept of Trade openness (TO)

Study of Aggarwal and Karwasra (2024), Tariq et al. (2024), Saud et al. (2024), Ma et al. (2024b), Wang et al. (2024d) and Qing et al. (2024) investigates that, Cross-border commerce of goods, services, and resources affects economic growth and environmental sustainability. Trade, investments, and technology transfers stimulate economic growth, as evidenced in developing economies and the Belt and Road Initiative. Trade openness improves GDP but harms the environment. Trade openness raises industrial carbon emissions but encourages cleaner technologies, cutting emissions, according to studies. Empirical research suggests that trade openness harms the environment but integration increases sustainability. Trade diversification, especially import diversification, minimises carbon emissions and environmental issues. Policymakers must support green energy, eco-innovation, and trade-open regulatory frameworks to balance economic growth and environmental protection. Cross-border commerce of goods, services, and resources affects economic growth and environmental sustainability. Trade, investments, and technology transfers stimulate economic growth, as evidenced in developing economies and the Belt and Road Initiative. Trade openness improves GDP but harms the environment. Trade openness raises industrial carbon emissions but encourages cleaner technologies, cutting emissions, according to studies. Empirical research suggests that trade openness harms the environment but integration increases sustainability. Trade diversification, especially import diversification, minimises carbon emissions and environmental issues. Policymakers must support green energy, eco-innovation, and trade-open regulatory frameworks to balance economic growth and environmental protection.

3.2.5 Proxy of Trade Openness

Study of Gandjon Fankem and Feyom (2024), Cheng et al. (2024), İşcan and Demirel (2024), Degbedji et al. (2024), Qing et al. (2024), and Sachan et al. (2024) finds that, Trade openness is a crucial indicator that influences carbon emissions in BRICS nations. The study employs the natural logarithm of trade openness (LNTO) as a measure of this indicator. The results from both DOLS and FMOLS cointegration techniques reveal that LNTO has a favorable impact on reducing carbon emissions in BRICS economies. This finding suggests that increased trade openness contributes to improved environmental quality without compromising economic growth. The positive effect of trade openness is attributed to technological spillovers, which facilitate the introduction of clean and advanced technologies across these nations. As trade barriers are lowered, BRICS countries gain access to more efficient and environmentally friendly production methods, leading to reduced reliance on polluting technologies. For instance, the exchange of renewable energy technologies and sustainable practices through trade channels has accelerated the adoption of cleaner energy solutions in countries like India and China. However, the study also notes that further improvements in trade-related rules and regulations are necessary to maximize the environmental benefits of trade openness in BRICS nations.

3.2.6 Anticipate relationship

The study of Pata et al. (2023a), Tariq et al. (2024), Wang et al. (2024a), Li and Chen (2024) and Xu et al. (2023) shows the relationship between trade openness (TO) and green growth presents a dual narrative, shaped by context and regulatory frameworks. On the positive side, trade openness fosters green economic growth, carbon efficiency, and sustainability, as seen in emerging economies Tariq et al. (2024) and regions like ASEAN, where it reduces CO2 emissions and promotes renewable energy integration. Similarly, studies on Latin America and global contexts highlight its role in energy transitions and long-term economic growth. Conversely, trade openness can harm environmental quality, increasing emissions and reducing green productivity, particularly in regions like OECD and G20 countries or Belt and Road nations, where weak institutional frameworks exacerbate these effects. Notably, studies like Xu et al. (2023) underscore that institutional quality can mitigate such negative impacts, emphasizing the pivotal role of governance and regulations in shaping the TO-green growth dynamic.

3.2.7 Concept of Institutional quality (IQ)

Study of Degbedji et al. (2024), Alsagr and Ozturk (2024), Wahab et al. (2024), Tawiah et al. (2024) and Huang et al. (2024) finds that, Institutional quality plays a pivotal role in promoting sustainable development and green economic growth by shaping governance frameworks and regulatory mechanisms. High institutional quality characterized by political stability, control of corruption, government effectiveness, and strong regulatory frameworks—enhances green investment, mitigates environmental degradation, and supports sustainable resource management. Studies in West African Economic and Monetary Union (WAEMU) countries highlight how robust institutions foster green economic growth by ensuring accountability and effective governance, while weak institutions can impede progress. Similarly, in OECD nations, institutions significantly influence emissions control, trade practices, and the adoption of renewable energy.

Empirical evidence suggests that corruption undermines green growth, with a 1% increase in corruption leading to a substantial decrease in environmental sustainability outcomes. This underscores the importance of transparency and anti-corruption measures. Moreover, sound institutional frameworks encourage green technologies and efficient use of natural resources, as seen in regions like China, where governance drives positive spillovers in green development across neighboring areas. To enhance institutional quality, policymakers must prioritize eliminating corruption, improving regulatory frameworks, and fostering good governance. These measures are essential for balancing economic growth with environmental sustainability and achieving long-term development goals such as those outlined in Agenda 2030.

Institutional quality is pivotal for green economic growth and environmental sustainability, with key indicators including government effectiveness, rule of law, and control of corruption, which ensure efficient public services, fairness, and resource allocation toward green initiatives. Political stability encourages long-term investments in sustainable practices, while regulatory quality balances economic and environmental objectives. Transparency and voice and accountability empower stakeholders and build trust in sustainability-focused policies. Market integration and governance enhance resource utilization and mitigate vulnerabilities like the resource curse. These indicators, demonstrated in regions like WAEMU and OECD countries, reduce environmental degradation and drive green growth by fostering effective governance and achieving Sustainable Development Goals (SDGs).

3.2.8 Proxy of Institutional quality

Study of Degbedji et al. (2024), Li and Tong (2024), Huang et al. (2024) and Huang et al. (2024) investigate that, Institutional quality is pivotal for green economic growth and environmental sustainability, with key indicators including government effectiveness, rule of law, and control of corruption, which ensure efficient public services, fairness, and resource allocation toward green initiatives. Political stability encourages long-term investments in sustainable practices, while regulatory quality balances economic and environmental objectives. Transparency and voice and accountability empower stakeholders and build trust in sustainability-focused policies. Market integration and governance enhance resource utilization and mitigate vulnerabilities like the resource curse. These indicators, demonstrated in regions like WAEMU and OECD countries, reduce environmental degradation and drive green growth by fostering effective governance and achieving Sustainable Development Goals (SDGs).

3.2.9 Anticipate relationship

Study of Akhtar et al. (2024), Zheng et al. (2024), Appiah et al. (2022), Rehman et al. (2023), Farooq et al. (2023), Obobisa et al. (2023) and Shahbaz et al. (2023) investigates the relationship between institutional quality (IQ) and green growth is multifaceted, with both positive and negative outcomes depending on context and governance structures. On the positive side, strong institutions promote green investment, reduce emissions, and enhance sustainability, as seen in studies on green economies and E-7 nations, where effective governance mitigates ecological impact. Similarly, institutional quality improves environmental outcomes in Sub-Saharan Africa and supports renewable energy in ASEAN countries. Conversely, in certain contexts like low-income OIC economies and African countries, weak or misaligned institutions may increase emissions or degrade environmental quality. Moreover, regional variations, such as Europe’s positive outcomes versus Asia’s challenges, highlight the role of economic conditions and policy frameworks in shaping IQ's impact on green growth.

3.3 Data and variable of the study

Table 2: Data, variables and data source

Variable	Definition	Proxy	Author	Expected Sign	Possible Data Source
Natural Resource Rent (NRR)	The study of (Moses and Brigham, 2024), (Simionescu et al., 2024), (Simionescu et al., 2024), (Yu et al., 2024) and (Pratibha et al., 2024) investigate that, Natural resource rent refers to the economic value derived from the extraction and utilization of natural resources, including land, minerals, and forests.	1. Natural Resource Rent as a Percentage of GDP 2. Sectoral Rent Contributions 3. Genuine Savings Rate 4. Resource Exports as a Share of Total Exports 5. Government Resource Revenues 6. Natural Resource Depletion Rate 7. Resource Governance Index	(Zhang et al., 2022), (Nguyen et al., 2024), (Liang et al., 2024), (Okolo et al., 2024), (Alsagr and Ozturk, 2024), (Cheng et al., 2020, Khan et al., 2020) and (Ma et al., 2024a)	1. Mixed 2. Mixed 3. +Ve 4. -Ve 5. +Ve 6. -Ve 7. +Ve	Natural Resource Governance Institute (NRGI), Transparency International, World Bank, International Resource Panel (UNEP), UN Comtrade Database, UNCTAD, IMF
Trade Openness (TO)	Trade openness refers to the extent to which a country allows free exchange and cross border commerce of goods,	1) Natural Logarithm of Trade Openness (LNTO): 2) Trade-to-GDP Ratio 3) Import/Export Diversification Index	(Gandjon Fankem and Feyom, 2024), (Cheng et al., 2024), (İşcan and Demirel, 2024),	1) +Ve 2) Mixed 3) +Ve	World Bank, IMF. OECD Statistics, UNCTAD (United Nations Conference on Trade and Development), ITC (International Trade Center)

	services, and technologies with other nations (Gandjon Fankem and Feyom, 2024), (Cheng et al., 2024)		(Degbedji et al., 2024), (Qing et al., 2024), and (Sachan et al., 2024)		
Institutional Quality (IQ)	According to (Alsagr and Ozturk, 2024), (Wahab et al., 2024), (Tawiah et al., 2024) Institutional quality refers to the effectiveness of governance frameworks, including political stability, rule of law, and anti-corruption measures, promoting sustainable development.	1. Political Stability 2. Control of Corruption 3. Government Effectiveness 4. Rule of Law 5. Regulatory Quality 6. Voice of Accountability	(Akhtar et al., 2024), (Zheng et al., 2024), (Appiah et al., 2022), (Rehman et al., 2023), (Farooq et al., 2023), (Obobisa et al., 2023) and (Shahbaz et al., 2023)	1. +Ve 2. +Ve 3. +Ve 4. +Ve 5. +Ve 6. +Ve	World Bank Governance Indicators, Transparency International, Economist Intelligence Unit (EIU), Freedom House, World Justice Project, World Bank Doing Business Report

3.4 Estimation strategy

3.4.1 Cross-Section Dependence (CSD)

Cross-Section Dependence (CSD) analysis helps identify if there is any cross-sectional dependence within a panel data set. This is crucial because, without it, we might draw incorrect conclusions due to the correlation between units in the error terms of regression models. In Pesaran (2004) introduced a diagnostic test for detecting CSD, which calculates the average of the pairwise correlation coefficients of the residuals from individual regressions. This test is valuable for uncovering cross-sectional dependence, which can cause issues and lead to inaccurate results in panel data models. Recognizing this dependence is essential for ensuring the reliability and validity of the model's outcomes.

Cross-section dependence analysis is essential to identify and address any dependencies between cross-sections in a panel data set. If these dependencies are not properly accounted for, the results may lead to inefficient and biased parameter estimates. By detecting CSD, researchers can adjust their models to incorporate these dependencies, ensuring more accurate and reliable results. This technique is particularly useful when the cross-sectional dependence arises from common shocks or unobserved variables affecting multiple units in the panel. The test proposed by Pesaran (2004) is straightforward to implement and has proven effective in detecting cross-sectional correlations, making it a valuable tool for researchers working with panel data.

The primary test statistic proposed by Pesaran (2004) is the CD test, which is defined as: Equation of CSD:

(Equation 1)

$$\text{CD}=\sqrt{\frac{2T}{N(N-1)}}\sum_{I=1}^{N-1}\sum_{J=i+1}^{N}(\hat{\rho}_{ij})$$

where:

- T- time dimension,
- N- cross-sectional dimension,
- ρij- sample estimate of the pairwise correlation of the residuals from a standard panel model for cross-sectional units for i and j.

3.4.2 Slope Homogeneity Analysis

In slope homogeneity analysis, we test whether the regression coefficients (slopes) are the same across all cross-sectional units in a panel data model. This involves testing the null hypothesis that the slopes are equal across the different units. Blomquist and Westerlund (2013) proposed a test for slope homogeneity that considers both serial correlation (correlation over time within the same unit) and cross-sectional dependence (correlation between different units). This test helps determine whether it is reasonable to pool data from all units together and assume the same slope for everyone, or if it is better to estimate the slopes individually for each unit. Using this test, researchers can make more informed decisions about how to structure their models and whether pooling data is appropriate.

The equation for Blomquist and Westerlund (2013) is as follow:

The Equation of Slope Homogeneity Analysis:

(Equation 2)

$$\hat{\Delta}\text{HAC}=\sqrt{N}\left(\frac{N^{-1}\hat{S}_{HAC-P}}{\sqrt{2p}}\right)$$

Where,

- Δ_{HAC}= The test statistic for assessing slope homogeneity.
- N = Number of cross-sectional units.
- S_{HAC}= HAC estimator for the variance-covariance matrix of the slope coefficients.
- $\sqrt{2p}$ = This term could be a scaling factor or adjustment factor for the model, potentially relating to the number of parameters or the data's structure.

The validity of panel data estimation depends on whether the panel is slope-homogeneous, meaning that the regression slopes are consistent across all cross-sectional units. Blomquist and Westerlund (2013) test is particularly useful for checking slope homogeneity while accounting for serial correlation (correlation over time within the same unit) and cross-sectional dependence (correlation between different units). This test is considered an improvement over the original test, as it provides a more accurate way to assess homogeneity. By using this test, researchers can make a better decision on whether to use individual estimates for each unit or to pool the data together. This helps ensure that the results from the estimation are valid and reliable.

3.4.3 Unit root analysis

To account for cross-sectional dependence, the Cross-Sectional Augmented Dickey-Fuller (CADF) test, developed by Pesaran (2007), is used to detect the presence of unit roots in panel data. This test is an extension of the standard Augmented Dickey-Fuller (ADF) test, but it includes cross-sectional averages of the lagged levels and the first differences of each individual series in the panel. By adding these cross-sectional averages, the CADF test can more accurately identify unit roots in the data, even when there is cross-sectional dependence between the different units. This approach helps ensure that the test remains valid and reliable under conditions where cross-sectional dependence exists.

Including these dependencies in the model improves the accuracy of unit root tests when compared to traditional methods. This is crucial because the results of these tests will influence the properties of the data, which in turn are used for subsequent analyses like cointegration tests or regressions. In other words, any issues with the unit root detection can affect the reliability of later analyses. The CADF test is particularly helpful for econometricians working with panel data because it can effectively manage cross-sectional dependence, which is often present in real-world datasets. This ability ensures that the test gives more reliable results when dealing with complex panel data structures.

CIDF Test Equation:

(Equation 3)

$$\Delta Y_{it}=a_i+b_i y_{i,t-1}+c_i\bar{y}_{t-1}+d_i\Delta\bar{y}_t+e_{it}$$

Here

The equation represents the change in the dependent variable (ΔY_{it}) for unit i at time t. Here's a brief description of the components:

- ΔY_{it}: Change in the dependent variable for unit i at time t (first difference).
- a_i: Individual-specific intercept capturing unchanging characteristics of unit i.
- $b_i y_{i,t-1}$: Lagged value of the dependent variable for unit i at time t-1, with b_i indicating its impact on the current change.
- $c_i \bar{y}_{t-1}$: Cross-sectional average of the dependent variable at time t-1, with c_i measuring its effect on unit i's change.
- $d_i \Delta \bar{y}_t$: Change in the cross-sectional average of the dependent variable at time t, with d_i measuring its effect on unit i.
- e_{it}: Error term for unit i at time t, capturing unobserved factors affecting the dependent variable.

Another method suggested by Pesaran (2007) is the Cross-sectional Augmented IPS (CIPS) test, which is an extension of the Im, Pesaran, and Shin (IPS) test for detecting unit roots in panel data. The CIPS test improves upon the IPS test by incorporating cross-sectional averages in the augmented Dickey-Fuller regressions, addressing the issue of cross-sectional dependence. The test statistic is then calculated by combining the individual test statistics from all the units in the panel, providing a more accurate assessment of unit roots in the presence of cross-sectional dependence. This makes the CIPS test more suitable for panel data where dependencies across units are present.

CIPS Test Equation:

(Equation 4)

$$\text{CIPS}=\frac{1}{N}\sum_{i=1}^{N} CADF_i$$

Where,

- CIPS = The test statistic for determining unit roots in panel data with cross-sectional dependence.
- N= The number of cross-sectional units in the panel.
- CADF_i = The Cross-Sectional Augmented Dickey-Fuller statistic for the i^{th} unit.

The CIPS test helps unit root tests handle cross-sectional endogeneity, which is a common issue in macroeconomic and financial panel data. Cross-sectional endogeneity occurs when there are correlations between different units in the data, which can lead to biased or inaccurate results. By accounting for this issue, the CIPS test ensures that unit roots are identified correctly. As a result, the test improves the accuracy and efficiency of econometric analysis, providing more reliable results when working with panel data that exhibit these cross-sectional dependencies.

3.4.4 Cointegration Analysis

Cointegration analysis examines whether variables that are integrated to the same degree share a long-term relationship. Westerlund (2007), Westerlund (2005) developed cointegration tests specifically designed to account for structural shifts and cross-sectional endogeneity, which are common in panel data. These tests rely on structural dynamics and error correction models, making them particularly effective and reliable when the data exhibits cross-sectional dependence or experiences significant structural changes over time. This approach ensures more accurate identification of long-run relationships even under complex data conditions.

Equation for Westerlund (2007) is as follows:

(Equation 5)

$$\Delta y_{it}=\delta_i{}'d_i+\alpha_i(y_{i,}\mathrm{t}{-}1-\beta_i{}'x_{i,t-1})+\sum_{j=1}^{p_i}\alpha_{ij}\Delta y_{i,t-j}+\sum_{j=0}^{q_i}y_{ij}\Delta x_{i,t-j}+e_{it}$$

- Δy_{it}: Change in the dependent variable y for unit i at time t (first difference).
- $\delta_i{}'d_i$: Individual-specific intercepts for unit i, capturing characteristics that remain constant over time.
- $\alpha_i(y_{i,}t-1-\beta_i{}'x_{i,t-1})$: The error correction term, showing the relationship between lagged values of y (dependent variable) and x (independent variable). α_i indicates the speed of adjustment to equilibrium, and β_i measures the influence of lagged x.
- $\sum_{j=1}^{p_i}\alpha_{ij}\Delta y_{i,t-j}$: The effect of past changes in y over p_i lags, with α_ij as the coefficient.
- $\sum_{j=0}^{q_i}y_{ij}\Delta x_{i,t-j}$: The effect of past changes in x over q_i lags, with y_ij as the coefficient.
- e_{it}: The error term capturing unobserved factors affecting y that aren't included in the model.

These tests are important because they account for structural breaks and cross-sectional dependence, which are common in real-world data. By addressing these issues, the tests help identify the long-term relationships between variables, improving the accuracy and trustworthiness of the results. Researchers rely on these tests to ensure that their long-term economic models are based on solid statistical foundations, making the conclusions more reliable and meaningful.

Westerlund (2007), Westerlund (2005) introduced robust panel cointegration tests that account for cross-sectional dependence, which arises when individual units in a panel dataset, such as countries or firms, are correlated. Extending the Engle-Granger approach, these tests include four statistics Group Mean Test (GT), Pooled Mean Group Test (PMG), Average Group Test (Ga), and Panel Cointegration Test designed to identify common long-term relationships in panel data. Westerlund's methods are particularly useful in macroeconomic and financial datasets, where cross-sectional dependence is common, offering improved robustness, handling heterogeneous error terms, and providing accurate, versatile tools for panel cointegration analysis.

3.4.4.1 Pedroni

Pedroni (2004) proposes a series of cointegration tests that account for differences or heterogeneity across panel data. These tests include multiple statistical methods to examine cointegration in panels where the units may vary in terms of their individual characteristics, such as the degree of variation in the data. The aim is to accurately detect long-term relationships between variables, even when the panels have different features or behaviors.

Equation of Pedroni:

(Equation 6)

$$Y_{it}=\alpha_i + \beta_i x_{it} + e_{it}$$

These tests are valuable because they address the issues of heterogeneity in the panel data, which are often present in real-world studies. Heterogeneity refers to the differences between individual units in the panel, such as varying behaviors or characteristics. By handling these differences, the tests provide a more reliable way to detect cointegration, making them highly suitable for panel data analysis. This method enhances the accuracy of analyzing long-term relationships by considering all the relevant factors and ensuring a more comprehensive understanding of how the variables are related over time.

Pedroni (2004) introduced a comprehensive framework for panel cointegration testing, extending Johansen's procedure to panel data. It offers seven tests grouped into within-dimension tests (analyzing individual units) and between-dimension tests (examining the entire panel), accounting for individual and common trends. These tests are widely used in macroeconomic and financial studies to detect cointegration vectors while considering heterogeneity across units, where long-term relationships may differ. Pedroni's method is versatile and applicable to large panels, providing flexibility with multiple test statistics and adapting to datasets with varying relationships across cross-sectional units

3.4.4.2 Kao

In the context of panel data, Kao (1999) created a residual-based cointegration test, which specifically examines the null hypothesis that there is no cointegration between the variables. This test simplifies the process of testing for cointegration by using only the residuals (the differences between the observed and predicted values) from the panel regression models. By focusing on these residuals, Kao's test helps identify long-term relationships between the variables without needing complex procedures, making it a more straightforward method for cointegration analysis in panel data.

Equation of Kao:

(Equation 7)

$$Y_{it}=\gamma_i + x'_{it}\beta + e_{it}$$

The test is straightforward and easy to implement, which makes it a useful tool for researchers. Its simplicity doesn't make the method more complicated, and importantly, it doesn't reduce the ability to detect cointegration. This ensures that the test remains effective for studying long-term relationships in panel data without sacrificing accuracy or reliability in identifying connections between variables.

Kao (1999) introduced a panel cointegration test tailored to datasets with homogeneous slope coefficients, extending the Engle-Granger two-step procedure. It tests the null hypothesis of no cointegration by performing unit root tests on the residuals from the cointegration regression, with stationarity indicating cointegration. Commonly applied in macroeconomic and financial studies, Kao's method is ideal for analyzing long-run relationships when variables are assumed to have consistent relationships across units. Its simplicity, focus on homogeneity, and applicability to cross-country panel studies make it a widely used and intuitive approach to panel cointegration analysis.

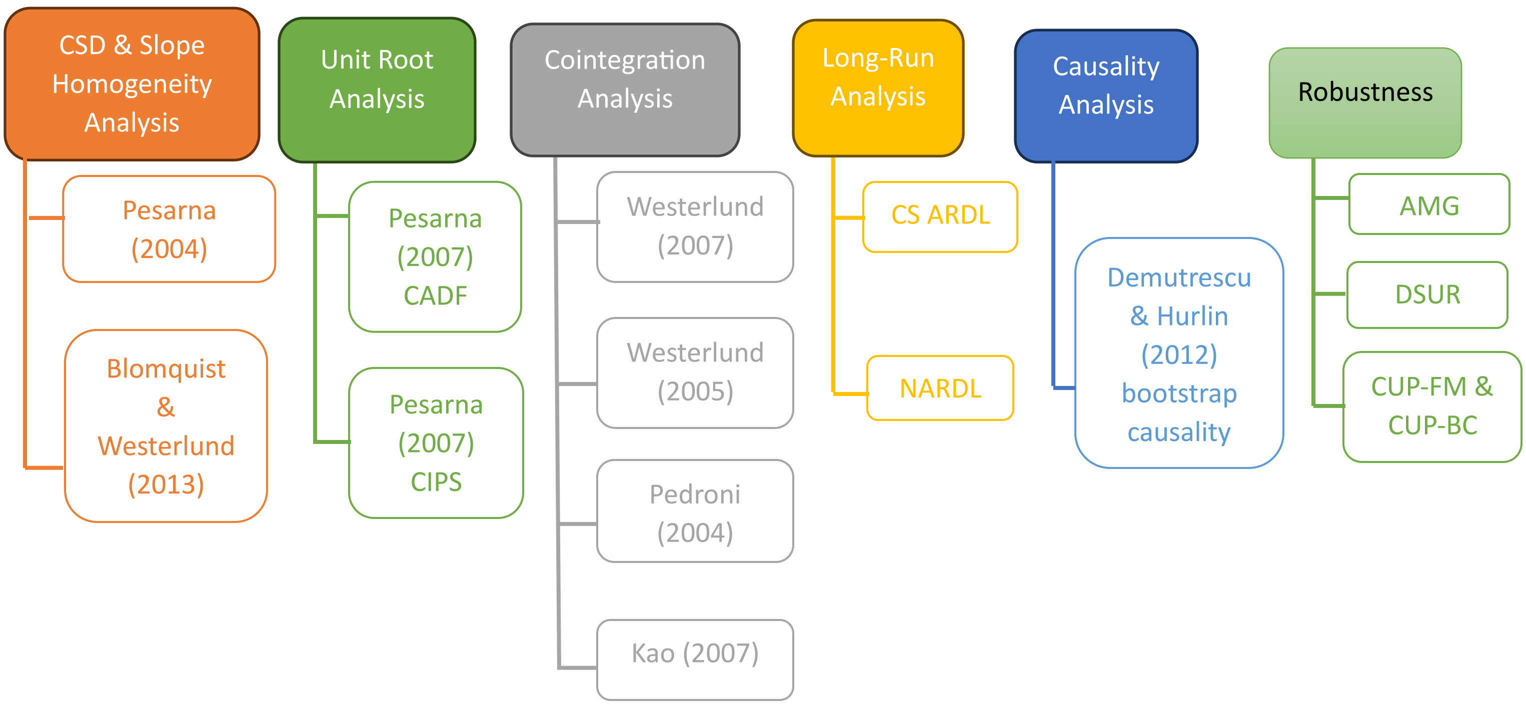

Figure 2: Estimation Strategy

3.4.5 Long-Run Analysis

3.4.5.1 The Cross-Sectional Augmented Autoregressive Distributed Lag (CS-ARDL)

The Cross-Sectional Augmented ARDL (CS-ARDL) model is an enhanced version of the standard ARDL (Autoregressive Distributed Lag) model. What sets it apart is that it addresses cross-sectional endogeneity, a common issue in panel data where units (such as individuals, firms, or countries) may be correlated with each other. The CS-ARDL model does this by incorporating the cross-sectional mean of both the dependent and independent variables into the analysis. This adjustment helps improve the accuracy of the results by accounting for interdependencies between units in the data, making the model more reliable for real-world panel data analysis.

The CS-ARDL model effectively handles cross-sectional dependence, providing more accurate and efficient estimates, especially when there are common disturbances affecting the units in the panel data. By addressing this issue, the method improves the reliability of both long-run and short-run estimates in panel data models. This is particularly useful for researchers, as it helps avoid endogeneity problems, which often arise in macroeconomic and financial data, as well as in other datasets with cross-sectional dependencies. Essentially, the CS-ARDL model makes it possible to obtain more trustworthy results by correcting for these complex interdependencies between units in the data.

Equation of CS-ARLD:

(Equation 8)

$$\overline{GG}_{it} = e_{it} + \sum_{j=1}^{p} \beta_{ij}\overline{GG}_{i,t-j} + \sum_{j=0}^{q} \gamma_{ij}\overline{NRR}_{i,t-j} + \sum_{j=0}^{q} \partial_{tj}\overline{TO}_{i,t-j} + \sum_{j=0}^{p} \emptyset_{tj}\overline{IQ}_{i,t-j} + e_{it}$$

The CS-ARDL (Cross-Sectionally Augmented Autoregressive Distributed Lag) model extends the traditional ARDL framework to panel data, addressing cross-sectional dependence where entities like countries or firms influence each other. By incorporating cross-sectional averages of dependent and independent variables, it captures interdependencies while estimating both short- and long-term relationships. CS-ARDL is particularly suited for economic and financial datasets, enabling analysis of long-run equilibrium and short-run dynamics. Its advantages include robust handling of cross-sectional dependence, flexibility with stationary and non-stationary data, and efficient estimation by accommodating heterogeneous slope coefficients across units.

3.4.5.2 Nonlinear Autoregressive Distributed Lag (NARLD)

The NARDL (Nonlinear Autoregressive Distributed Lag) model includes the asymmetric long-run and short-run dynamics of the variables in the analysis. Unlike the standard ARDL (Autoregressive Distributed Lag) model, which assumes linear relationships, the NARDL model is more flexible. It allows for nonlinear adjustments and captures asymmetric responses to changes in external (or exogenous) variables. This means that the model can account for situations where the effect of an explanatory variable may differ depending on whether it increases or decreases, providing a more accurate representation of real-world data where such asymmetries are often observed.

The NARDL (Nonlinear Autoregressive Distributed Lag) model provides an effective way to analyze economic structures that may have asymmetrical behaviors. This means it helps researchers understand how an economic variable responds differently to positive and negative shocks (unexpected changes) in the system. Unlike linear models, which treat all changes the same, NARDL captures the reality that economic responses can vary depending on whether the shock is positive (an increase) or negative (a decrease).

By doing so, the NARDL model gives a more accurate and realistic view of how economic variables interact with each other, especially in complex systems where these asymmetric effects are important. Researchers often turn to NARDL when linear models fail to provide a clear or accurate description of the economic relationships they are studying.

Equation of NARDL (Nonlinear Autoregressive Distributed Lag):

(Equation 9)

$$\Delta GG_{it}=\beta_{0i}+\beta_1 GG_{i,t-1}+\beta_2 NRR_{i,t-1}+\beta_3 TO_{i,t-1}+\beta_4 IQ_{i,t-1}+\sum_{j=1}^{N-1}\gamma ij\ \Delta GG_{i,t-j}+\sum_{j=0}^{M-1}(\gamma_{ij}^{+}+\Delta NRR_{i,t-j}^{+}+\gamma_{ij}^{-}\Delta NRR_{i,t-j}^{-})+\sum_{m=0}^{Q-1}(\gamma_{ij}^{+}+\Delta TO_{i,t-m}^{+}+\gamma_{im}^{-}\Delta TO_{i,t-m}^{-})+\sum_{n=0}^{R-1}(\gamma_{in}^{+}+\Delta IQ_{i,t-n}^{+}+\gamma_{in}^{-}\Delta IQ_{i,t-n}^{-})+\mu_i+e_{it,}$$

$$\mathrm{NRR}_i^{+}=\sum_{k=1}^{t}\Delta\mathrm{NRR}_{ik}^{+}=\sum_{k=1}^{T}\mathrm{MAX}(\Delta\mathrm{NRR}_{ik},0),$$

$$\mathrm{NRR}_i^{-}=\sum_{k=1}^{t}\Delta\mathrm{NRR}_{ik}^{-}=\sum_{k=1}^{T}\mathrm{MIN}(\Delta\mathrm{NRR}_{ik},0).$$

$$\mathrm{TO}_i^{+}=\sum_{m=1}^{t}\Delta\mathrm{TO}_{im}^{+}=\sum_{m=1}^{T}\mathrm{MAX}(\Delta\mathrm{TO}_{im},0),$$

$$\mathrm{TO}_i^{-}=\sum_{m=1}^{t}\Delta\mathrm{TO}_{im}^{-}=\sum_{m=1}^{T}\mathrm{MIN}(\Delta\mathrm{TO}_{im},0).$$

$$\mathrm{IQ}_i^{+}=\sum_{n=1}^{t}\Delta\mathrm{IQ}_{in}^{+}=\sum_{n=1}^{T}\mathrm{MAX}(\Delta\mathrm{IQ}_{in},0),$$

$$\mathrm{IQ}_i^{-}=\sum_{n=1}^{t}\Delta\mathrm{IQ}_{in}^{-}=\sum_{n=1}^{T}\mathrm{MIN}(\Delta\mathrm{IQ}_{in},0).$$

The NARDL (Nonlinear Autoregressive Distributed Lag) model extends the ARDL framework to capture asymmetric and nonlinear relationships between variables. Unlike traditional ARDL models, which assume linear effects, NARDL accounts for situations where positive and negative changes in an independent variable have different impacts on the dependent variable, such as economic reactions to rising versus falling oil prices. It analyzes both short-run dynamics and long-run equilibrium relationships, incorporating positive and negative changes separately. NARDL is particularly useful for studying economic phenomena exhibiting asymmetric behavior, offering versatility for stationary and non-stationary data, flexibility in small samples, and the ability to model complex dynamics more realistically.

3.4.6 Causality Analysis

3.4.6.1 Dumitrescu and Hurlin (2012) bootstrap causality

To study the causal relationship in panel data, we use the Bootstrap Panel Granger Causality test developed by Dumitrescu and Hurlin (2012). This test is specifically designed to handle cross-sectional dependence (when units in the panel data are related to each other) and to correct for small sample bias (which can occur when there are limited data points). Because of these complexities, the test uses bootstrap methods, which involve repeatedly sampling from the data to make more reliable inferences about causality. This approach ensures that the results are robust and accurate, even in cases where the data may have these potential issues.

Bootstrap causality tests are particularly useful because they are less affected by cross-sectional dependence (the situation where units in panel data are interrelated). This makes them well-suited for handling complex panel data structures where traditional methods may struggle. These tests help researchers identify causal relationships in economic and financial data, areas where other methods might give misleading results due to issues like bias or inconsistency. By using bootstrap techniques, the test ensures more accurate and reliable conclusions, even when dealing with challenging data characteristics.

Equation of Causality Analysis:

(Equation 10)

$$Y_{it} = \alpha_i + \sum_{k-1}^{p} \gamma ik\, Y_{i,t-k} + \beta_{ik} X_{i,t-k} + \mu_{it}$$

(Equation 11)

$$W_{NT}^{Hnc} = N^{-1} \sum_{i-1}^{N} W_{i,t}$$

(Equation 12)

$$\text{Z}=\sqrt{\frac{N}{2P} \times \frac{T-2P-5}{T-P-3}} \times [\frac{T-2P-3}{T-2p-1} \overline{W} - P]$$

The Bootstrap Causality Test, as developed by Dumitrescu and Hurlin (2012), is an advanced statistical method used within a Vector Autoregressive (VAR) framework to assess the causal relationships between time series data. The bootstrap methodology involves estimating the VAR model, resampling the residuals to create pseudo-residuals, and repeatedly testing for causality to build an empirical distribution of the test statistic, which provides a p-value based on how often extreme test statistics occur in the bootstrap samples. This approach is particularly advantageous because it does not rely on traditional assumptions about the distribution of test statistics, making it effective for small sample sizes and datasets exhibiting non-stationarity or structural breaks. Additionally, it accommodates both linear and nonlinear relationships, offering robustness against model misspecification and enhancing flexibility in various econometric applications.

3.4.7 Robustness

3.4.7.1 Augmented Mean Group (AMG)

To estimate long-run relationships in panel data models that have cross-sectional dependence (where units in the panel are related to each other), we use the Augmented Mean Group (AMG) estimator. The AMG estimator helps address time-invariant unobserved heterogeneity, meaning it controls for factors that differ between panel units but do not change over time, such as certain fixed characteristics. These factors may affect all units in the panel similarly. By accounting for these unobserved influences, the AMG estimator allows for more accurate and efficient estimates of the long-run coefficients in the model, ensuring that the results are reliable even in complex data structures.

The AMG (Augmented Mean Group) estimator is useful because it helps account for cross-sectional dependence in panel data, ensuring that the relationships between variables are properly estimated. This method is especially effective in macroeconomic and financial analysis, where the data often include common disturbances that affect all units in the panel in a similar way. By considering these shared disturbances, the AMG estimator ensures that long-run relationships are estimated accurately, even when the panel data includes dependencies between units. This improves the reliability and credibility of the results, making the findings more trustworthy and robust for empirical analysis.

Equation of AMG:

(Equation 13)

$$Y_{it} = \alpha_i + \beta_i x_{it} + \gamma_i \bar{y}_t + \epsilon_{it}$$

Here:

- y_{it}- dependent variable,
- x_{it}- explanatory variables,
- $\bar{y}_t$- cross-sectional mean of y,
- α_i, β_i, and γ_i- parameters to be estimated,
- ϵ_{it} $-$ error term.

The Augmented Mean Group (AMG) estimator, developed by Eberhardt and Teal (2010), enhances the traditional Mean Group (MG) estimator by incorporating unobserved common factors and allowing for heterogeneous slopes across different cross-sections. AMG is particularly useful in analyzing how countries, firms, or regions respond differently to economic, social, or environmental factors by accommodating varying slope coefficients. It also addresses cross-sectional dependence arising from shared shocks, such as financial crises or pandemics, by integrating cross-sectional averages to control for these unobserved common factors. Additionally, AMG effectively handles nonstationarity in macroeconomic and environmental variables, making it suitable for long-run analyses without the need for stationarity. Overall, AMG provides more realistic results in panel data settings characterized by diverse units and global influences.

3.4.7.2 Dynamic Seemingly Unrelated Regression (DSUR)

Equation of DUSR:

(Equation 14)

$$GG_{it} = \alpha_i + \beta_1 NRR_{it} + \beta_2 TO_{it} + \beta_3 IQ_{it} + \vartheta_{plt} + \epsilon_{it}.$$

The Dynamic Seemingly Unrelated Regression (DSUR) estimator, introduced by Mark et al. in 2005, is designed for dynamic panel data analysis, particularly when dealing with cointegration and cross-sectional dependence. By simultaneously estimating a system of equations using Seemingly Unrelated Regression (SUR), DSUR effectively captures long-run relationships while addressing endogeneity and serial correlation in regressors. It is particularly adept at handling nonstationarity and cointegration, making it suitable for scenarios where dynamic adjustments occur over time, such as the effects of institutional reforms on green growth. DSUR's key advantages include its ability to model interdependencies among multiple dependent variables, enhancing efficiency and robustness, as well as providing comprehensive system-wide estimates that leverage information from all equations involved. This makes DSUR an invaluable tool for analyzing complex economic systems characterized by strong interrelations and lagged effects.

3.4.7.3 Continuously Updated Fully Modified and Bias Corrected (CUP-FM and CUP-BC)

The Continuously Updated and Bias Corrected (CUP-BC) and Fully Modified (CUP-FM) methods also enhance the estimation of cointegration in panel data. These techniques improve the accuracy of estimating long-term relationships by addressing issues like endogeneity (where variables are correlated with the error term) and cross-sectional dependence (where units in the panel are related to each other). Both methods ensure that the estimates of the parameters are efficient (meaning they make the best use of the data) and consistent (meaning the estimates are reliable even with large datasets). By correcting these potential problems, CUP-BC and CUP-FM provide more precise and trustworthy results in panel data analysis.

These methods provide accurate and reliable long-term estimates when analyzing panel data. By correcting for potential biases, they improve the credibility of long-run analyses. This means that researchers can trust the estimates they obtain, knowing that the methods help eliminate any distortions that might arise from common issues in the data, such as endogeneity or cross-sectional dependence. As a result, these techniques offer more trustworthy insights into the long-term relationships between variables in panel data systems.

Equation of CUP-FM:

(Equation 15)

$$\hat{\beta}_{CUP-BC} = arg\, min \sum_{i=1}^{N} (y_{it} - \alpha_i - \beta x_{it})^2$$

The Continuously Updated Fully Modified (CUP-FM) estimator, developed by Bai et al. (2009) is designed to estimate long-run relationships in nonstationary panel data while effectively addressing cross-sectional dependence. Utilizing a fully modified OLS framework, CUP-FM incorporates corrections for endogeneity and serial correlation, making it robust against biases from unobserved common factors. This method is particularly useful for analyzing cointegrated relationships in panels characterized by large cross-sections (N) and time dimensions (T). Building on CUP-FM, the Continuously Updated Bias-Corrected (CUP-BC) estimator introduces a bias correction term to enhance the efficiency of long-run coefficient estimates, further improving finite-sample performance and providing reliable results in complex datasets with strong cross-sectional dependence. Both methods are essential in panel data econometrics as they address challenges such as heterogeneity, nonstationarity, and endogeneity, ensuring accurate inference and robust estimation of long-term economic relationships.

Chapter 04: Estimation and interpretation

4.1 Pre-estimation assessment

Bersvendsen and Ditzen (2021) SH test detects structural breaks in time series data indicating relationship changes between variables over time. The structural breaks are significant at the 1% level (***), as shown by the Delta Statistic and Adjusted Delta Statistic.

Table 3: Slope of Heterogeneity

Panel B: SH test of Bersvendsen and Ditzen (2021)			
	Delta Statistic	Adjusted Delta Statistic	SH exits
Model	3.9935***	5.657***	Yes

There strong cross-sectional dependence across all test variables. The Breusch and Pagan (1980) test consistently reports very high statistics, with the highest being (426.354) for GG, indicating strong dependence. Similarly, Pesaran (2004) shows significant dependence across variables, but with lower statistics, the highest being (44.521) for FDI. Pesaran et al. (2008) also report substantial dependence, with GG having the highest value of (235.789), reflecting marked differences compared to other tests. For Pesaran (2006), the dependence strength varies more notably, with statistics ranging from (5.106) for NRR to (35.985) for TO, indicating variability in detecting dependencies under different conditions. Juodis and Reese (2022) also present lower values, with GG at (11.9574) and TO at (10.5724), yet all remain statistically significant. Among the variables, GG and FDI exhibit the highest statistics across most tests, suggesting these are the most strongly dependent. Conversely, metrics like NRR and FD show relatively lower values in Breusch and Pagan (1980) and Pesaran (2004), though significant dependencies are still observed. These pervasive cross-sectional dependencies likely stem from common shocks, shared economic policies, or global factors influencing all panel units uniformly.

Table 4: Cross-Sectional dependency test

	(Breusch and Pagan 1980)	Pesaran (2004)	Pesaran, Ullah et al. (2008)	Pesaran (2006)	Juodis and Reese (2022)
GG	426.354***	40.302***	235.789***	32.954***	11.9574***
NRR	241.215***	23.814***	132.746***	5.106***	8.0967***
IQ	232.84***	26.82***	139.82***	18.334***	11.4656***
TO	281.032***	24.39***	176.913***	35.985***	10.5724***
FDI	403.417***	44.521***	218.577***	7.965***	8.7856***
FD	211.75***	39.721***	122.752***	25.293***	8.9994***

The panel unit root test results indicate that most variables are nonstationary at their level, implying that their statistical properties (mean and variance) vary over time, rendering regression results unreliable if left untreated. After first differencing, all variables are stationary (significant test statistics with (***) implying that they are integrated of order one or (1). These variables are, therefore, random walk variables, and their trends must be taken into account by using first differences in further analysis to avoid spurious relationships.

The table presents unit root test results for several variables (GG, NRR, IQ, TO, FDI, and FD) using both the Herwartz and Siedenburg (2008) and CIPS tests, assessing their behavior at levels and first differences. For GG (Green growth), both tests indicate that it has a unit root at the level but becomes stationary at the first difference, with the Herwartz and Siedenburg test showing a significant t-statistic of (-7.113), and the CIPS test confirming stationarity with a t-statistic of (–4.431). NRR (Natural Resource Rent) also exhibits a unit root at the level, but is stationary at the first difference according to both tests, with significant t-statistics of (-4.255) Herwartz and Siedenburg (2008) and (-3.801) (CIPS). For IQ (Institutional Quality), similar results are observed with stationarity after differencing, supported by t-statistics of (-2.241) Herwartz and Siedenburg (2008) and (-2.388) (CIPS). TO (Trade Openness), FDI (Foreign Direct Investment), and FD (Financial Development) also show a pattern of non-stationarity at the level and stationarity at the first difference, with the CIPS test consistently reporting significant results at the first difference.

Table 5: Panel Unit Root test

Variables	**CADF test statistic**		**CIPS test statistic**		**Herwartz and Siedenburg -2008**	
	Level	**first difference**	**Level**	**first difference**	**Level**	**first difference**
GG	-2.649	-7.113***	-1.662	-4.431***	0.0476	8.7616***
NRR	-2.231	-4.255***	-2.56	-3.801***	0.3683	4.3136***
IQ	-2.917	-2.241***	-2.664	-2.388***	-0.3057	4.0715***
TO	-2.043	-6.206***	-1.312	-5.649***	1.6366	5.7536***
FDI	-1.352	-7.457***	-2.598	-5.93***	1.4852	4.2433***
FD	-1.088	-6.35***	-2.669	-5.888***	-0.9626	4.4033***

The results from the cointegration tests using the methods developed by Westerlund and Edgerton (2008) and Westerlund and Edgerton (2007) are summarized in the panel cointegration test table. These tests evaluate whether a long-term relationship exists between the variables being studied. To determine the significance of cointegration, the Westerlund and Edgerton (2008) test statistics are compared against their p-values. If the p-value is smaller than a pre-set threshold (usually 0.05 or 0.01), it indicates that the variables are cointegrated, meaning they share a long-term relationship and tend to move together over time.

In the first scenario, where no shifts in the data are considered, both the LMг and LMΦ test statistics are statistically significant ($P < 0.05$), suggesting the presence of a long-term relationship between the variables. When a mean shift is introduced into the data, both statistics remain statistically significant ($P < 0.05$), implying that the cointegration relationship persists, and a stable long-term relationship is still present. In a scenario involving a regime shift (a structural change in the data), the LMг and LMΦ statistics are again significant ($P < 0.05$), indicating that even with the change, the long-term relationship between the variables remains intact.

Second, the results from the Westerlund and Edgerton (2007) cointegration test are presented for different models and specifications. This test also includes Gt and Ga statistics, which provide further insight into the presence of cointegration under various conditions. The Gt and Ga test statistics are statistically significant ($P < 0.05$ or $P < 0.01$) across model, supporting the cointegration of the variables in each of the respective model. Both model specification and test type (Pt or Pa) do not matter, as these findings suggest strong evidence of a long-run relationship among the variables, thereby confirming that they move together over time.

Table 6: Panel Cointegration test

	no shift		mean shift		regiem shift	
	LMг	LMΦ	LMг	LMΦ	LMг	LMΦ
Model 1	-3.8728***	-2.4576***	-2.3203***	-4.856***	-2.5183***	-3.4068***
	Gt	Ga	Pt	Pa		
Model	-12.227***	-10.615***	-14.508***	-10.21***		

In the short run, the variables show significant effects on Green growth (GG). The table shows the short-run effects of several variables, each with its coefficient, standard error, and t-statistic for two models. For NNR, the negative coefficients (-0.0316 and -0.0505) suggest a negative relationship with the dependent variable, meaning higher NNR values lead to lower outcomes, with the second model showing a stronger effect. IQ has positive coefficients (0.0518 and 0.0384), indicating a positive relationship with the dependent variable higher IQ values lead to higher outcomes, with a smaller effect in the second model. For TO, the first model shows a negative coefficient (-0.0301), while the second model shows a positive one (0.0256), suggesting a reversal in the relationship between the models. The t-statistics, which are larger in absolute value for significant coefficients, indicate the strength of these relationships, with higher t-statistics (e.g., for IQ in the second model) suggesting stronger statistical significance.

Table 7: Long-run and short-run coefficient: CS-ARDL

	Coefficient	std.error	t-stat		Coefficient	std.error	t-stat
Short-run				Short-run			
NNR	-0.0316	0.0104	-3.0384	NNR	-0.0505	0.0057	-8.8596
IQ	0.0518	0.0069	7.5072	IQ	0.0384	0.0025	15.36
TO	-0.0301	0.0103	-2.9223	TO	0.0256	0.0076	3.3684
FDI	-0.0669	0.0024	-27.875	FDI	0.0825	0.0059	13.983
FD	-0.0424	0.0093	-4.5591	FD	0.0644	0.0024	26.8333
C	0.0659	0.0044	14.9772	ECT	-0.1499	0.0053	-28.283
CD test				0.03336			
Wooldridge Test for autoco				0.288124			

Normality test			0.923109			
Remsey RESET test			0.034587			

4.1.1 Asymmetric Long-run and short-run coefficients: NARDL

In the long run, the variables show significant effects on Green growth (GG). The table shows the effects of NRR+ (positive non-linear relationship), NRR- (negative non-linear relationship), and IQ+ (positive IQ) on the dependent variable in both the long run and short run. For NRR+, the long-run coefficient of -0.1492 indicates a significant negative relationship, meaning higher values of NRR+ lead to a decrease in the dependent variable, while in the short run, the coefficient is positive (0.0052), suggesting a small positive effect. For NRR-, the long-run coefficient of -0.1143 also reflects a negative relationship, with a stronger negative effect in the short run (-0.0366). IQ+ shows a positive long-run coefficient (0.0965), indicating a positive relationship with the dependent variable, but a negative short-run effect (-0.0419), meaning higher IQ+ values initially lead to a decrease in the dependent variable before the longer-term positive impact is realized.

Table 8: Asymmetric Long-run and short-run coefficients: NARDL

	LONG-RUN			Short-run		
Variables	Coefficient	st.error	t-stat	Coefficient	st.error	t-stat
NRR+	-0.1492	0.0322	-4.6335	0.0052	0.0025	2.08
NRR-	-0.1143	0.0229	-4.9912	-0.0366	0.0048	-7.625
IQ+	0.0965	0.0416	2.3197	-0.0419	0.0078	-5.3717
IQ-	0.1347	0.04	3.3675	-0.0128	0.0041	-3.1219
TO+	-0.1478	0.0394	-3.7512	0.0085	0.0075	1.1333
TO-	-0.0962	0.0281	-3.4234	0.004	0.006	0.6666
FDI	-0.1142	0.0178	-6.4157	0.0525	0.0059	8.8983
FD	-0.1494	0.0302	-4.947	0.0224	0.0074	3.027
ECT				-0.1465	0.027	-5.4259
$W_{FinTecH}$	8.1285			9.8202		
W_{EX}	10.1482			14.0322		
W_{GG}	11.2659			9.911		

The table presents the relationships between several variables, with coefficients and t-statistics showing the strength and significance of these connections. GG exhibits significant positive correlations with NRR, IQ, and TO. The coefficient for GG and NRR is 3.6843 with a t-statistic of 4.3294, indicating a strong positive relationship ($p < 0.05$). Similarly, GG and IQ have a positive relationship with a coefficient of 4.3294 and a t-statistic of 5.3708 ($p < 0.01$), suggesting that higher GG is associated with better IQ. For GG and TO, the coefficient is 4.5239 with a t-statistic of 3.8947 ($p < 0.05$), implying that GG also positively influences TO. The relationship between GG and FDI shows a coefficient of 3.8947 with a t-statistic of 4.1051 ($p < 0.05$), further reinforcing the positive connections between GG and these variables. NRR shows a positive correlation with IQ (coefficient 2.747, t-stat 2.6939) and FDI (coefficient 0.9458), both statistically significant. Additionally, IQ positively correlates with TO (coefficient 4.5685, t-stat 4.8152) and FDI (coefficient 1.8299), with high significance. TO has a significant negative relationship with GG (coefficient -5.5568, t-stat 5.8569), highlighting a complex, nuanced interaction in the data. These relationships show varying strengths and significance, with multiple positive and negative correlations between the variables in the table.

The test shows significant relationships between the variables, with Green Growth (GG) positively impacting Natural Resource Rent (NRR), Institutional Quality (IQ), Trade Openness (TO), and Foreign Direct Investment (FDI). Improved governance is associated with better outcomes in these areas, as evidenced by positive coefficients and strong t-statistics (e.g., 3.6843 for GG and NRR, indicating a robust positive relationship). NRR also positively influences IQ and FDI, suggesting that higher resource rents lead to better institutional quality and attract more foreign investment, as shown by coefficients of 2.747 and 0.9458, respectively. Furthermore, IQ has a significant impact on FDI, with a coefficient of 1.8299, and a positive relationship with GG (3.8034), indicating that higher institutional quality enhances both governance and investment. Trade Openness (TO), however, shows a mixed relationship, negatively influencing FDI and NRR, implying that while trade openness may encourage foreign investment, it could also lower the rents from natural resources in the long run.

Table 9: Causality test

	GG	NRR	IQ	TO	FDI	FD
		(3.6843)**	(4.3294)**	(5.3708)***	(4.5239)**	(3.8947)**
GG		[3.8833]	[4.5632]	[5.6609]	[4.7682]	[4.1051]
	1.7577		(2.747)*	(2.6939)*	(3.188)**	0.9458
NRR	[1.8526]		[2.8954]	[2.8394]	[3.3602]	[0.9968]
IQ	1.4569	(3.8034)**		(3.543)**	(2.5951)*	1.8299
	[1.5356]	[4.0087]		[3.7343]	[2.7352]	[1.9287]
	(5.5568)***	(2.0435)*	(4.5685)**		(5.3634)***	0.8979
	[5.8569]	[2.1539]	[4.8152]		[5.653]	[0.9464]
TO						
	(6.0595)***	(3.2954)**	(5.9798)***	(3.6578)**		1.0722
FDI	[6.3867]	[3.4733]	[6.3027]	[3.8553]		[1.1301]
FD	(3.5855)**	1.56	(5.9564)***	(5.2529)***	(3.8395)**	
	[3.7791]	[1.6442]	[6.278]	[5.5365]	[4.0468]	

4.2 **Post-estimation evaluation**

4.2.1 Robustness test

The table presents the estimated coefficients, t-statistics, and standard errors for three model specifications: MG, AMG, and CS-ARDL, evaluating the relationship between independent variables (NRR, IQ, TO, and FDI) and the dependent variable. For Natural Resource Rent (NRR), the MG model shows a coefficient of 0.146 with a high t-statistic of 28.0769, indicating a strong positive relationship. The AMG model reports a slightly lower coefficient of 0.106 (t-statistic of 10.3921), while the CS-ARDL model gives a coefficient of 0.1479 (t-statistic of 23.4761), both indicating significant positive impacts. For Institutional Quality (IQ), the coefficients across all models are positive, with the MG model showing the highest coefficient of 0.0846 (t-statistic of 44.5263), followed by AMG (0.0862, t-statistic of 7.4956) and CS-ARDL (0.0794, t-statistic of 11.8507), all demonstrating a strong positive relationship with the dependent variable. Trade Openness (TO) shows a negative relationship, with coefficients of -0.0245 in MG (t-statistic of -3.2236), -0.027 in AMG (t-statistic of -6.279), and -0.121 in CS-ARDL (t-statistic of -10.614), indicating that increased trade openness reduces the dependent variable. Finally, Foreign Direct Investment (FDI) exhibits a negative impact across all models, with coefficients of -0.0643 (MG, t-statistic of -9.597), -0.0566 (AMG, t-statistic of -4.8793), and -0.1614 (CS-ARDL, t-statistic of -14.958), suggesting that FDI has a significant adverse effect on the dependent variable. The varying coefficients and t-statistics across models highlight the robustness of the relationships and the sensitivity to model specifications.

Table 10: Robustness test

	MG			AMG			CS-ARDL		
	Coef	t-stat	std.error	Coef	t-stat	std.error	Coef	t-stat	std.error
NNR	0.146	0.0052	28.0769	0.106	0.0102	10.3921	0.1479	0.0063	23.4761
IQ	0.0846	0.0019	44.5263	0.0862	0.0115	7.4956	0.0794	0.0067	11.8507
TO	-0.0245	0.0076	-3.2236	-0.027	0.0043	-6.279	-0.121	0.0114	-10.614
FDI	-0.0643	0.0067	-9.597	-0.0566	0.0116	-4.8793	-0.1614	0.0108	-14.9444
FD	0.0811	0.0035	23.1714	0.1123	0.002	56.15	0.0262	0.0089	2.9438
C	5.1668	1.149	4.4967	2.2874	0.9005	2.5401	5.9459	0.396	15.0148
CD test		0.0229			0.0233			0.0294	
Wooldridge Test		0.0318			0.0321			0.0223	
Normality test		0.0219			0.0256			0.028	
Remsey RESET test		0.0305			0.0267			0.0241	

Chapter 05: Discussion of the study findings

This discussion synthesizes the key findings from the extensive literature review on the effects of natural resource rents, trade openness, and institutional quality on green growth. The analysis draws insights from numerous empirical studies to provide a comprehensive understanding of these relationships and their implications for sustainable development.

The impact of natural resource rents on green growth presents a complex and often contradictory picture across different studies and contexts. Several key themes emerge from the literature: Multiple studies indicate that natural resource rents can positively contribute to economic growth and development. For instance, Zhang et al. (2022) found a positive relationship between natural resources and China's ecological footprint, suggesting that resource exploitation supports economic expansion. Similarly, Li et al. (2022) observed that natural resource rents had positive effects on the ecological footprint, indicating their role in driving economic activity. However, this economic growth often comes at an environmental cost. Gyamfi et al. (2022) revealed a positive relationship between total natural resources rent and pollution in G7 economies, highlighting the environmental degradation associated with resource exploitation. This aligns with findings from Luo et al. (2023), who identified a strong positive correlation between natural resource rents and carbon emissions, especially in low-income countries.

The analysis reveals strong cross-sectional dependence across all variables, with differences in the magnitude of dependence depending on the test used. The Breusch and Pagan (1980) test consistently reports very high dependence, particularly for GG (Green Growth), with the highest statistic of 426.354. Similarly, Pesaran (2004) detects significant dependence, though with lower statistics, the highest being 44.521 for FDI (Foreign Direct Investment). The Pesaran et al. (2008) test also shows substantial dependence, with GG again having the highest value of 235.789, while (Pesaran, 2006) shows more variation, ranging from 5.106 for NRR (Natural Resource Rent) to 35.985 for TO (Trade Openness). Juodis and Reese (2022) report comparatively lower values for GG (11.9574) and TO (10.5724), though these remain statistically significant. Among the variables, GG and FDI consistently exhibit the highest cross-sectional dependence, suggesting these variables are particularly sensitive to shared global factors, such as common economic shocks or international policies. In contrast, NRR and FD show weaker dependencies, though still significant. These pervasive dependencies likely reflect common global or regional economic influences that affect all units in the panel similarly.

The results of the unit root tests, specifically the Herwartz and Siedenburg (2008) and CIPS tests, confirm this pattern for several variables GG (Green Growth), NRR (Natural Resource Rent), IQ (Institutional Quality), TO (Trade Openness), FDI (Foreign Direct Investment), and FD (Financial Development). For GG, both tests show a unit root at the level, but stationarity is achieved after first differencing, with significant t-statistics of (-7.113) from Herwartz and Siedenburg and (-4.431) from CIPS. A similar pattern is observed for NRR, with both tests showing stationarity after differencing, and significant t-statistics of (-4.255) Herwartz and Siedenburg (2008) and (-3.801) (CIPS). For IQ, stationarity is also achieved after differencing, with t-statistics of (-2.241) Herwartz and Siedenburg (2008) and (-2.388) (CIPS). Likewise, TO, FDI, and FD show non-stationarity at their levels, but become stationary after first differencing, with the CIPS test confirming significance for all variables. The results suggest that while the variables are non-stationary in their levels, differencing them transforms them into stationary variables. This transformation is essential for conducting reliable regression analysis and avoiding potential issues associated with non-stationary data.

The literature presents conflicting evidence on how natural resource rents influence green innovation and sustainable development. Some studies suggest a positive relationship. For example, Okolo et al. (2024) found that various rents, including oil and natural gas, significantly promote innovation. This indicates that resource wealth can potentially drive technological advancements in the green sector. Conversely, other research points to negative impacts. Ngo (2024) observed that abundant resources negatively affect Green Total Factor Productivity (GTFP), particularly in regions with higher green production. This suggests that resource abundance might lead to complacency in pursuing green technologies and practices. Similarly, Alsagr and Ozturk (2024) found that resource rent negatively impacts green investment, potentially hindering the transition to more sustainable economic models. The impact of natural resource rents appears to vary depending on the type of resource and the economic context of the country. Fu and Liu (2023) observed that mineral rents and natural gas rents positively affect sustainable development, while forest rents have a negative impact. This nuanced finding underscores the importance of considering specific resource types when analyzing their effects on green growth.

The results from the cointegration tests by Westerlund and Edgerton (2008) and Westerlund (2007) provide strong evidence of a long-term relationship between the variables. In the Westerlund and Edgerton (2008) test, both LM_Γ and LM_Φ statistics are significant ($p < 0.05$) across different scenarios no shifts, mean shifts, and regime shifts indicating that the cointegration relationship persists even with changes in the data structure. Similarly, the Westerlund (2007) test, using the Gt and Ga statistics, confirms significant cointegration ($p < 0.05$ or $p < 0.01$) across all models, supporting the presence of a stable long-term relationship among the variables regardless of model specification. These findings collectively confirm that the variables move together over time, reinforcing the existence of a robust long-run relationship.

The economic development level of a country also plays a crucial role. Wang et al. (2024a) found that higher natural resource rents improve ecological quality in certain contexts. However, this positive effect is often moderated by factors such as corruption levels and institutional quality. The literature emphasizes the critical role of governance and policy in determining the ultimate impact of natural resource rents on green growth. Chen et al. (2023) highlighted that institutional quality can mitigate CO_2 emissions by combating corruption and upholding the rule of law. This suggests that the negative environmental impacts of resource exploitation can be moderated through effective governance structures. Furthermore, several studies point to the importance of targeted policies to channel resource rents towards sustainable development. A negative association between ecological footprint and factors such as renewable energy, technological change, and ecological policies. This indicates that resource-rich countries can leverage their wealth to invest in green technologies and sustainable practices, provided they have the right policy framework in place. The short-run effects of various variables on Green Growth (GG) show significant relationships, with the direction and strength of these relationships varying across models. For NNR (Natural Resource Rent), both models show negative coefficients (-0.0316 and -0.0505), indicating a negative relationship with GG. This suggests that higher NNR values are associated with lower green growth outcomes, with the second model demonstrating a stronger negative effect. In contrast, IQ (Institutional Quality) exhibits positive coefficients (0.0518 and 0.0384), implying that better institutional quality is associated with higher green growth, though the effect is slightly weaker in the second model. TO (Trade Openness) presents an interesting pattern: the first model shows a negative relationship (-0.0301), while the second model shows a positive coefficient (0.0256), suggesting a reversal in the relationship between the two models.

The t-statistics, which reflect the significance of these coefficients, are larger in absolute value for the significant variables, indicating that variables like IQ (in the second model) have a stronger statistical significance in influencing green growth. Overall, the findings suggest that institutional quality positively impacts GG, while natural resource rents generally have a negative effect, with trade openness exhibiting a mixed relationship depending on the model.

In the long run, the variables significantly affect Green Growth (GG), with some showing non-linear relationships and varying short- and long-term effects. For NRR+ (positive non-linear relationship), the long-run coefficient of -0.1492 indicates a significant negative relationship, suggesting that higher values of NRR+ are associated with a decrease in green growth outcomes. However, in the short run, the coefficient is positive (0.0052), indicating a small positive effect in the short term, before the long-run negative effect becomes more pronounced. For NRR- (negative non-linear relationship), the long-run coefficient of -0.1143 also reflects a negative relationship with GG, and the short-run effect is even stronger with a coefficient of -0.0366, indicating a more immediate negative impact. On the other hand, IQ+ (positive Institutional Quality) shows a positive long-run coefficient (0.0965), implying that improvements in institutional quality have a positive effect on green growth in the long term. However, in the short run, the coefficient is negative (-0.0419), suggesting that better institutional quality initially leads to a decrease in green growth before the longer-term positive effects are realized. These findings highlight that while institutional quality may lead to positive outcomes for GG over time, the effects of natural resource rents (both positive and negative) are more complex, showing short-term positive impacts but long-term negative consequences for green growth.

The relationship between trade openness and green growth is multifaceted, with studies revealing both positive and negative impacts depending on various factors: Several studies highlight the potential negative environmental consequences of increased trade openness. Wang et al. (2024d) found that trade openness increases emissions, while trade diversification reduces them. This suggests that while general trade openness might lead to increased economic activity and associated emissions, diversifying trade partners and products could mitigate some of these negative effects. Similarly, Li and Chen (2024) observed that trade openness exacerbates species loss, with higher levels of biodiversity loss associated with increased openness. This points to the potential ecological risks of unrestricted trade, particularly in biodiversity-rich regions. The literature presents mixed findings on how trade openness affects renewable energy adoption and its environmental impacts. Ibrahim et al. (2022) found that only adverse effects of renewable energy and technology can mitigate emissions in the context of trade openness. This suggests that while trade might increase overall emissions, it can also facilitate the transfer of clean technologies and renewable energy solutions. Conversely, Xu et al. (2023) observed that growth in renewable energy and trade openness worsens the environment. This counterintuitive finding might be explained by the increased economic activity and consumption patterns associated with trade openness, potentially offsetting the positive impacts of renewable energy adoption.

The relationships between the variables presented in the table highlight several significant positive and negative correlations, with Green Growth (GG) showing strong positive associations with key factors such as Natural Resource Rent (NRR), Institutional Quality (IQ), and Trade Openness (TO). Specifically, GG is positively correlated with NRR, with a coefficient of 3.6843 and a t-statistic of 4.3294, indicating a robust positive relationship ($p < 0.05$). Similarly, GG and IQ exhibit a strong positive relationship, with a coefficient of 4.3294 and a t-statistic of 5.3708 ($p < 0.01$), suggesting that higher GG is linked to better institutional quality. The relationship between

GG and TO is also positive, with a coefficient of 4.5239 and a t-statistic of 3.8947 ($p < 0.05$), implying that improved governance positively influences trade openness. Moreover, GG is positively correlated with Foreign Direct Investment (FDI), with a coefficient of 3.8947 and a t-statistic of 4.1051 ($p < 0.05$), reinforcing the idea that better governance fosters higher foreign investment.

The literature reveals a complex relationship between trade openness, economic growth, and environmental quality. Afjal and Devi (2024) found an inverse relationship between GDP and CO2 emissions in low-growth economies, but a positive correlation in moderate and high-growth economies. This suggests that the environmental impacts of trade openness might depend on a country's stage of economic development. Adebayo et al. (2022) observed that trade openness hinders environmental quality, along with non-renewable energy consumption and economic growth. However, Dam and Sarkodie (2023) identified trade openness as a key indicator of environmental sustainability in Turkey, alongside real income and renewable energy consumption. These contrasting findings highlight the context-specific nature of trade openness impacts. The impact of trade openness on green growth appears to be influenced by sectoral composition and technological factors. Wang et al. (2023b) found that trade openness negatively affects renewable energy intensity. This could be due to increased competition from cheaper, potentially less environmentally friendly imports. However, Ozkan et al. (2023) observed that green technological innovation and financial development positively impacted carbon efficiency in China. This suggests that trade openness, when coupled with investments in green technology and supportive financial systems, can contribute to improved environmental outcomes.

The mixed findings on trade openness underscore the need for carefully crafted policies that maximize the benefits of trade while mitigating its potential negative environmental impacts. Pata et al. (2023b) found that trade openness stimulates the low-carbon footprint in the long run. This indicates that over time, trade can potentially facilitate the transition to more sustainable economic models, possibly through the diffusion of green technologies and practices. However, as Huang and Liu (2022) observed, trade openness can inhibit green productivity, but increasing regulations can alleviate its negative effects. This highlights the crucial role of environmental regulations and governance in shaping the relationship between trade openness and green growth.

The literature consistently emphasizes the critical role of institutional quality in promoting green growth and environmental sustainability: Numerous studies highlight the positive influence of strong institutions on environmental outcomes. Zheng et al. (2024) found that improved institutions significantly decrease emissions, particularly in contexts with stronger institutional frameworks. This suggests that enhancing institutional quality can be a powerful lever for promoting environmental sustainability. Similarly, Abudaqa and Ab-Samat (2024) observed that institutional quality, along with renewable energy and ecological innovations, is significant in reducing carbon emissions. This underscores the complementary role of strong institutions in supporting and amplifying the effects of green technologies and practices.

NRR itself shows a positive relationship with both IQ (coefficient 2.747, t-statistic 2.6939) and FDI (coefficient 0.9458), suggesting that higher natural resource rents contribute to improved institutional quality and attract more foreign investment. Additionally, IQ has a significant positive effect on both TO (coefficient 4.5685, t-statistic 4.8152) and FDI (coefficient 1.8299), indicating that better institutional quality enhances trade openness and foreign investment. However, the relationship between TO and GG is notably negative, with a coefficient of -5.5568 and a t-statistic of 5.8569, pointing to a more complex dynamic where increased trade openness might have a negative effect on green growth, potentially due to shifts in resource allocation or economic structure. These findings show that better governance (GG) positively impacts natural resource rents, institutional quality, trade openness, and foreign investment, suggesting that effective governance can foster economic and environmental outcomes. However, the relationship between trade openness and green growth is more nuanced, as it can have a negative effect on green growth, possibly due to shifts in resource rents or other structural changes in the economy. These results also underscore the interconnectedness of these variables, highlighting those improvements in one area, such as governance, tend to lead to better outcomes in others, such as institutional quality and foreign investment.

Institutional quality appears to play a crucial role in determining whether natural resource abundance leads to positive or negative outcomes for green growth. Wang et al. (2023d) found that improving institutional quality could help eliminate the resource curse on green economic growth. Specifically, they observed that high-income countries saw increased promotion effects of natural resource abundance when institutional quality was above a certain threshold. This finding is particularly significant as it suggests that strong institutions can help resource-rich countries avoid the "paradox of plenty" and instead leverage their natural wealth for sustainable development.

The literature reveals important interactions between institutional quality, technological innovation, and green growth. Qayyum et al. (2024) found that institutional quality and Information and Communication Technology (ICT) protect the atmosphere, reduce ecological impact, and slow down pollution. This suggests that strong institutions can create an enabling environment for the development and adoption of green technologies. However, some studies present more nuanced findings. Sethi et al. (2024) observed that green finance, technology innovation, and institutional quality increase CO_2 emissions. This counterintuitive result might be explained by the increased economic activity associated with these factors, highlighting the complex relationships at play.

Institutional quality appears to have significant implications for financial development and economic growth, which in turn affect green growth trajectories. Karim et al. (2024) found that institutional quality enhances economic growth through its positive effect on the financial sector. This suggests that strong institutions can create a virtuous cycle of financial development and economic growth, potentially providing resources for green investments. Vatamanu and Zugravu (2023) observed that increased financial development positively impacts renewable energy consumption. Given the role of institutional quality in promoting financial development, this finding further underscores the indirect positive effects of strong institutions on green growth.

The results from the three model specifications MG, AMG, and CS-ARDL show significant relationships between the independent variables (NRR, IQ, TO, and FDI) and the dependent variable. Natural Resource Rent (NRR) and Institutional Quality (IQ) have strong positive relationships with the dependent variable, with NRR showing coefficients around 0.146 to 0.1479, and IQ ranging from 0.0794 to 0.0862, all with high t-statistics, indicating robust positive effects. In contrast, Trade Openness (TO) and Foreign Direct Investment (FDI) exhibit negative impacts, with TO showing coefficients from -0.0245 to -0.121 and FDI from -0.0643 to -0.1614, suggesting that increased trade openness and foreign investment are associated with a reduction in the dependent variable. The varying coefficients and t-statistics across the models highlight the sensitivity of these relationships to model specifications, with the CS-ARDL model showing the strongest negative effects for TO and FDI, and a slightly more moderate impact for NRR and IQ.

The impact of institutional quality on green growth appears to vary across different economic and geographic contexts. Hunjra et al. (2023) found a positive relationship between institutional quality and economic sustainability, but a negative relationship with CO2 emissions and deforestation. This nuanced finding highlights the potential trade-offs between different aspects of sustainability and the need for context-specific policies. Jahanger et al. (2023) observed that institutional quality negatively affects carbon dioxide emissions in their study context. However, Obobisa et al. (2023) found that institutional quality increases CO2 emissions. These contrasting findings underscore the complexity of the relationship between institutional quality and environmental outcomes, likely influenced by factors such as the stage of economic development, sectoral composition, and specific institutional arrangements.

The literature strongly suggests that improving institutional quality should be a key priority for policymakers aiming to promote green growth. Çitil et al. (2023) found that institutional quality and political stability increase air quality in G-20 countries. This indicates that strengthening governance structures and ensuring political stability can have direct positive impacts on environmental outcomes. Moreover, the moderating effect of institutional quality on the resource curse, as observed by Wang et al. (2023d), suggests that resource-rich countries should prioritize institutional reforms to maximize the benefits of their natural wealth for sustainable development.

While many studies focus on individual factors, some research provides insights into the interplay between natural resource rents, trade openness, and institutional quality in shaping green growth outcomes: The literature reveals complex interactions between these factors, often involving trade-offs between economic growth and environmental sustainability. For instance, Wang et al. (2023a) found that countries' economies improve after switching to renewable and nonrenewable energy sources, highlighting the role of both resource management and energy transitions in economic development. However, Zhang et al. (2024a) observed that while fintech and natural resource rents improve economic recovery, they harm environmental quality. This underscores the potential tensions between economic growth and environmental protection, and the need for carefully designed policies that balance these objectives.

Across the literature, the quality of governance and institutions emerges as a critical factor in determining the ultimate impact of natural resource rents and trade openness on green growth. Chen et al. (2023) highlighted that institutional quality can mitigate CO2 emissions by combating corruption and upholding the rule of law. This suggests that strong institutions can help countries navigate the challenges posed by resource abundance and increased trade openness. Several studies point to the crucial role of technological innovation in mediating the relationships between natural resource rents, trade openness, and green growth. Wang et al. (2024e) found that artificial intelligence promotes energy transition and reduces carbon emissions, with trade openness playing a mediating role. This highlights the potential for emerging technologies to drive sustainable development in the context of global trade.

Chapter 06: Conclusion and policy suggestion

6.1 Conclusion:

The study titled "The impact of Natural Resource Rent, Trade Openness, and Institutional Quality on Green Growth" provides a comprehensive analysis of the interplay between these factors and their impact on fostering green growth. The relationship between natural resource abundance and economic development is complex. While resource-rich countries may experience initial economic growth, the long-term effects can be detrimental if not managed properly. Effective governance and institutional frameworks are crucial in mitigating the "resource curse," ensuring that natural resource wealth contributes to sustainable development rather than leading to economic volatility and dependency. Countries with robust governance structures can leverage their natural resources to invest in green technologies and sustainable practices, thereby promoting green growth. Trade policies that encourage eco-innovation, reduce carbon footprints, and promote trade diversification can significantly influence green growth. However, the impact of trade openness on environmental sustainability varies. Some countries benefit from global market integration by adopting cleaner technologies and practices, while others face challenges due to increased environmental degradation from trade-related activities. The study highlights the importance of aligning trade policies with environmental goals to ensure that trade openness contributes positively to green growth. Strong institutions are vital for implementing green policies, enforcing environmental regulations, and creating frameworks that support sustainable practices. The quality of governance directly affects the effectiveness of green growth initiatives, with better governance leading to more sustainable outcomes. Institutions play a critical role in setting the stage for green investments, ensuring transparency, and fostering an environment conducive to sustainable development. Investment in green technologies is essential for decoupling economic growth from environmental degradation. Innovations in renewable energy, energy efficiency, and sustainable production processes are pivotal in driving industries towards greener practices. The study emphasizes the need for continuous technological advancement to support green growth, highlighting the role of research and development in this transition. Transitioning from traditional economic models to those focused on green growth involves integrating green technologies into production processes. This not only reduces environmental harm but also opens new economic opportunities in sectors like renewable energy. The study suggests that economic models need to evolve to incorporate sustainability as a core principle, thereby fostering green growth. Urban areas present both challenges and opportunities for green growth. Sustainable urban planning, green building practices, and efficient transportation systems are crucial for reducing carbon footprints and promoting sustainability. The research underscores the importance of urban development strategies that prioritize green infrastructure and sustainable living. Access to finance through green bonds, venture capital for clean tech startups, and other financial mechanisms is critical for supporting green investments. Financial markets can incentivize sustainable practices through mechanisms like carbon pricing. The study highlights the role of financial innovation in driving green growth by providing the necessary capital for sustainable projects. Global agreements and partnerships facilitate technology transfer, financial assistance, and policy alignment towards sustainability goals, making international cooperation a cornerstone of green growth. The research emphasizes the importance of collaborative efforts in addressing global environmental challenges and promoting green growth. Increasing public awareness through education and campaigns can shift consumer behavior towards sustainability, supporting demand for green products and practices. The study points out that public engagement is essential for the success of green growth initiatives, as it drives market demand for sustainable solutions. Improving resource efficiency through technological advancements and sustainable practices is fundamental to green growth, reducing waste and enhancing productivity. The research underscores the need for efficient resource management as a key driver of sustainable development.

6.2 Policy Suggestions:

Based on the findings, the following policy suggestions are proposed to enhance green growth:

- Implementing policies that promote sustainable resource usage and environmental conservation directly supports green growth by balancing economic development with ecological preservation. By establishing frameworks to manage natural resource rents, governments can channel revenues from resource extraction into green investments, such as renewable energy, energy-efficient infrastructure, and conservation projects. This ensures that natural resources are used responsibly and their benefits are reinvested in sustainable development, reducing overexploitation and environmental degradation. Additionally, conservation policies protect ecosystems, enhance biodiversity, and maintain natural services like clean air and water, which are critical for long-term economic and social well-being. Together, these policies foster a transition to a green economy where resource use is efficient, equitable, and aligned with environmental sustainability.
- Trade policies that encourage eco-innovation, reduce carbon footprints, and promote trade diversification play a crucial role in supporting green growth by integrating environmental sustainability with economic development. Eco-innovation drives the development and adoption of green technologies and sustainable practices, improving resource efficiency while reducing waste and environmental damage. Policies aimed at reducing carbon footprints, such as carbon pricing and incentives for low-emission products, encourage the production and consumption of environmentally friendly goods, aligning economic growth with climate goals. Diversifying trade across sectors with lower ecological impacts reduces dependency on resource-intensive industries, fostering resilience and sustainability. Moreover, prioritizing environmental standards in trade agreements, such as eco-labeling and restrictions on unsustainable imports, mitigates environmental degradation while promoting fair competition. Together, these policies create a balanced approach to economic development, ensuring that growth is both robust and environmentally sustainable.
- Enhancing institutional quality supports green growth by creating a strong foundation for the effective implementation of sustainable initiatives. Improved governance structures provide transparency, accountability, and strategic direction, enabling the consistent enforcement of environmental policies and ensuring that green growth objectives are met. Reducing corruption minimizes the misallocation of resources and ensures that investments in sustainability projects, such as renewable energy or conservation programs, are utilized effectively and achieve their intended outcomes. Regulatory quality fosters a predictable and stable policy environment, encouraging businesses and investors to adopt green technologies and practices with confidence. By establishing trust in institutions and creating a supportive framework, enhanced institutional quality ensures that green growth initiatives are implemented efficiently, driving economic development while safeguarding environmental sustainability.

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