

GREEN FINANCE AND RENEWABLE ENERGY AS DETERMINANTS OF CO₂ EMISSIONS: AN EMPIRICAL ANALYSIS OF DEVELOPING NATIONS

Hina Gul^{*1}, Iqra Rashid², Behram Awan³, Khawar Salim⁴

^{*1}Lecturer, Lahore School of Accountancy and Finance, University of Lahore,

²Research Scholar, Lahore School of Accountancy and Finance, University of Lahore,

^{3,4}Research Scholar, Lahore School of Accountancy and Finance, University of Lahore

¹hinagul@uolcc.edu.pk, ²iqraawan154@gmail.com, ³behramawan.work@gmail.com,

⁴khawarsalim95@gmail.com

DOI: <https://doi.org/10.5281/zenodo.21488457>

Keywords

CO₂ Emission, Green Finance, Renewable Energy, World Development Indicator, Developing Nation

Article History

Received: 07 January 2026

Accepted: 17 March 2026

Published: 31 March 2026

Copyright @Author

Corresponding Author: *

Hina Gull

Abstract

Between 2013 and 2024, this study investigates the relationships among carbon dioxide (CO₂) emissions, economic growth, energy intensity, and green finance across 28 countries selected from five regions in the World Development Indicator (WDI): the Middle East, North Africa, Afghanistan and Pakistan, South Asia, and North America. The research employs descriptive statistics, regression modeling, and correlation analysis to test three hypotheses using secondary panel data: whether green finance, GDP growth, and energy intensity significantly influence CO₂ emissions. Findings indicate that emissions, renewable energy use, and growth rates vary widely among nations. Correlation analysis shows moderate links between green finance and energy intensity with emissions, while GDP growth exhibits a weak correlation. Regression results reveal that green finance has a statistically significant yet unexpectedly positive effect on CO₂ emissions, suggesting transitional inefficiencies in the deployment of renewable energy. The lack of statistical significance and the negative correlation with GDP growth imply that economic development does not consistently drive emissions in the sample. The log-transformed regression confirms that efficiency improves with lower emissions, though the linear model deems energy intensity insignificant. Overall, the study concludes that green finance influences environmental outcomes in a complex and significant manner, highlighting the need for additional policies to ensure genuine decarbonization. Energy efficiency emerges as a key factor in reducing emissions, while GDP growth shows no direct effect. These findings contribute to the sustainability literature by illustrating the intricate interactions among financing, growth, and efficiency, and by emphasizing the necessity of region-specific policies to achieve meaningful reductions in CO₂ emissions.

INTRODUCTION

A major environmental and policy issue because of its substantial contribution to global warming and climate change (Mirziyoyeva & Salahodjaev, 2023; Sadiq et al., 2024). CO₂ emissions indicate

the extent to which the environment has been degraded by energy use, industrial processes, and economic growth, and are a frequently used indicator of ecological sustainability (Caglar et al.). Elevated CO₂ emissions not only increase global

temperature rise but also cause extreme weather events and affect human health and social welfare. This may cause economic and managerial challenges for governments and corporations worldwide. (Xu & Zhu, 2022). Policymakers have increasingly used CO₂ emissions indicators to craft climate policies, implement carbon emissions reduction targets, and assess the efficacy of environmental regulations. (Temesgen Hordofa et al., 2023).

In addition, CO₂ emissions affect global competitiveness, and nations with higher emissions may face international sanctions, carbon taxes, or trade restrictions, underscoring the strategic and economic significance of monitoring and controlling CO₂ emissions. (Alharbi et al., 2023). Consequently, curbing CO₂ emissions is a priority for achieving sustainable development goals and economic growth without compromising environmental integrity. (Leitão, 2014) Despite extensive research on CO₂ emissions, substantial gaps remain in the multidimensional understanding of drivers and policy levers that help reduce emissions. (Suhatman et al., 2024). A common thread in many studies is an emphasis on the relationship between the economy, energy use, or industrialization and an overlooking of the impact of emerging financial and governance mechanisms in determining environmental outcomes. (Hussain et al., 2025) Additionally, previous studies on the adoption of renewable energy sources and technological interventions have emphasized regional heterogeneity and cross-country differences, without giving due attention to integrating the moderating effects of governance and institutional effectiveness. (Mirziyoyeva & Salahodjaev, 2023).

Moreover, studies already presented often yield conflicting results regarding the Environmental Kuznets Curve and the relationship among policy uncertainty, corruption, and CO₂ mitigation. (Sadiq et al., 2024) These limitations thus underscore the importance of examining CO₂ emissions in the context of innovative policy instruments (e.g., green finance), governance effectiveness, and controlling for traditional economic and energy-related factors. Such an

integrated approach helps form a better understanding of the mechanisms by which financial and institutional interventions can reduce emissions, especially in the emerging and highly globalized context. (Xu & Zhu, 2022) Green finance has become part of a revolution in the development of a sustainable economy and environmental protection. (Alharbi et al., 2023) In terms of concept, green finance encompasses financial instruments, investments, and credit mechanisms that channel capital to projects aimed at environmentally sustainable development, renewable energy, eco-innovation, and carbon reduction. (Taghizadeh-hesary, 2020).

Empirical evidence indicates that green finance reduces carbon dioxide emissions by incentivizing the development of low-carbon technologies, increasing energy efficiency, and helping corporations adopt environmentally responsible practices. (Alharbi et al., 2023) Moreover, green finance enables risk sharing and mitigates financial barriers to investment in sustainable infrastructure, especially in emerging markets, where capital constraints impede environmental efforts (Bonsu et al., 2025). By fostering transparency, disclosure, and accountability in financial markets, green finance also helps align economic growth with environmental sustainability (Liu & Wu, 2023). Thus, green finance is a policy tool and a market mechanism for reducing CO₂ emissions, an important variable in modern environmental and economic studies. (Hussain et al., 2025) Governance effectiveness is another key factor affecting CO₂ emissions by influencing policies, regulatory compliance, and institutional capacity. (Xu & Zhu, 2022).

Conceptually, governance effectiveness is defined as the ability of governments to develop and implement environmental policies, enforce them, and monitor their implementation to ensure that financial and technological interventions have the desired ecological consequences. (Temesgen Hordofa et al., 2023). Studies suggest that enhanced governance reduces environmental degradation, as evidenced by stronger enforcement of emission regulations, increased transparency, and a reduced impact of policy

uncertainty and corruption. (Ali, 2024). Effective governance also enhances the efficiency of green finance by coordinating public and private sector activities and reducing procedural and institutional risks associated with sustainable investments. (Xu & Zhu, 2022). In areas where the institutional frameworks are weak or broken, financial interventions are often ineffective in achieving environmental outcomes. This reality speaks volumes about the role governance will play in achieving emission reduction goals, including moderating the effectiveness of any given financial intervention (Hussain et al., 2025; Liu & Wu, 2023).

Therefore, governance effectiveness is a must to ensure that green finance can be translated into a measurable reduction of CO₂ emissions and a sustainable environment in the long term (Hussain et al., 2025). GDP growth has been accepted as a control variable in most of the research on CO₂ emissions, where the economic activity scale, by which the environmental impacts of this economic sector are associated, is reflected (Mirziyoyeva & Salahodjaev, 2023). Economic growth affects emissions through energy use, industrial production, and infrastructure development, so it is necessary to account for GDP when analyzing impacts. (Caglar et al., 2022). Including a value for GDP growth as a control variable lets the researchers isolate the true effects of green finance/governance on CO₂ reduction (independent variables on emissions, controlling for some of the possible confounding effects brought about by economic growth. Moreover, GDP growth interacts with technological adoption, policy effectiveness, and financial instruments, further justifying its inclusion to ensure the analysis is not biased. (Mirziyoyeva & Salahodjaev, 2023). The other much-needed control variable is energy intensity, which measures how efficiently energy is used relative to economic performance and is directly associated with CO₂ emissions. (Razmjoo et al., 2021).

High energy intensity implies higher energy use per unit of GDP, which is usually associated with higher emissions, whereas low energy intensity signifies energy efficiency and cleaner production practices. (Zahoor et al., 2021). Controlling for

energy intensity will enable the analysis to separate the effects of green finance, governance effectiveness, and structural differences in energy use patterns across countries. The addition of energy intensity enables the research to obtain a more substantial evaluation of the mechanisms by which financial and institutional interventions affect CO₂ emissions, which can serve as strong guidance for policies and managerial decision-making. (Razmjoo et al., 2021).

Literature Review

Looking at the critical nexus between sustainability and macroeconomic performance, recent studies are placing greater emphasis on the role of environmental and globalization factors in determining economic growth. Leitão (2014). This study analyzes the relationships among economic growth, carbon dioxide emissions, renewable energy consumption, and globalization. Focusing on Portugal between 1970 and 2010, the research examines the dynamics of the variables in both the long run and the short run. By applying time-series econometric techniques such as OLS, GMM, unit root tests, VECM, and Granger causality analysis, the research ensures empirical robustness. Considering economic growth as the dependent variable of the study and carbon dioxide emissions, renewable energy use, and the globalization index as the explanatory variables, the study presents comprehensive evidence. The findings show that carbon dioxide emissions and renewable energy consumption are positively associated with economic growth. Moreover, globalization has a significant positive effect on economic growth. The causality analysis suggests a one-way cause from renewable energy to economic growth. From a policy point of view, the study draws inferences suggesting the promotion of renewable energy development, coupled with globalization-friendly policies. In addition, the following recommendation for future research is suggested: studies of the framework's additional impact on other economies by extending the indicators to them.

Exploring the longstanding and fundamental relationship between demographic change and economic performance, extensive literature in

recent years has focused on the joint dynamics of population growth and economic growth. Brida et al., (2024) This study explores the feedback effect between population and economic growth in countries. Covering 111 countries from 1960 to 2019, the study follows a general cross-country approach. Using a non-parametric model-free econometric framework, the research uses minimal spanning tree and hierarchical tree methods to find similarities in dynamic behavior. Considering economic growth and population growth as base variables, the analysis further incorporates GDP per capita, human capital, and life expectancy as complementary indicators. The findings reveal the existence of 3 country clubs with distinct dynamic growth trajectories. The results also reveal that these clusters do differ significantly in terms of broader socioeconomic evolution. From a policy perspective, the study makes an interesting suggestion that uniform demographic-growth policies might not work across heterogeneous economies. Moreover, future research is urged to move beyond single-model approaches and further explore the dynamics of interdependence across regions and stages of development.

Examining the underlying principles of consumer behavior and analysis of demand and costs, economic theory is constantly revisiting classical theories to explain decision-making under constraints. Nosheen et al. (2025) are revising the theoretical importance of the Slutsky Equation and its contemporary viability in microeconomic analysis. Tracing its intellectual origins to Slutsky's 1915 contribution, the study places the equation in both historical and contemporary economic contexts. Adopting a theoretical and analytical review methodology, the research synthesizes insights from utility maximization, welfare economics, and behavioral economics. Using price effect decomposition into income and substitution effects as the basic concepts, the research seeks to explain consumers' reactions to price changes. The analysis brings up empirical issues such as non-convex preferences, imperfect markets, and bounded rationality. The findings highlight how recent advances in computational methods and behavioral theories are enhancing

the applicability of the Slutsky framework. Further, the study demonstrates its relevance to taxation, subsidy design, environmental economics in general, and digital market dynamics. From a policy perspective, the review provides evidence-based guidance for policy formulation related to consumers and welfare policy. Finally, future research is recommended to integrate dynamic and intertemporal models to better fit the Slutsky Equation to evolving economic realities.

In the global challenge of climate change mitigation, more and more research now focuses on the contribution of renewable energy systems to reducing carbon emissions and achieving energy sustainability. (Razmjoo et al., 2021) On the other hand, it investigates sustainable hybrid renewable energy systems for electricity generation to reduce CO₂ emissions. Observing the high potential for renewable energy in Iran, the study is taking a country-specific approach. Using meteorological data and techno-economic assessment, the analysis is being made using HOMER simulation software. Considering hybrid setups with PV systems, wind turbines, diesel generators, batteries, fuel cells, electrolyzers, and hydrogen storage, the study is assessing performance (environmental and economic). The results show that the PV-wind-diesel-battery hybrid system is the most economical, with an energy cost of 0.151 USD/kWh and a return on investment of 15.6%. The results further demonstrated that a renewable energy fraction of more than 72% has a significant effect, with over 2,000 kg of CO₂ emissions reduced per house per year. Additionally, the integration of hydrogen-based technologies is helping to minimize excess electricity losses.

In recent studies examining the rising relevance of digital innovation and sustainable finance, an increasing focus has been placed on the role of financial technologies and green finance in driving sustainability performance in emerging economies. (Bonsu et al., 2025) We are exploring how Fintech and green finance affect sustainability performance, with information technology (IT) governance as the moderator. Conducting the study in three countries (Nigeria, Ghana, and

Cameroon) during the period of May-October 2024, the research is taking a cross-country banking sector perspective. Using survey results from 611 banking institutions, the analysis employs Partial Least Squares Structural Equation Modeling (PLS-SEM) and PROCESS models. Examining the challenge of achieving environmental sustainability and sustained economic growth, recent studies focus on the role of clean energy investment and financial development. (Zahoor et al., 2021) This is an analysis of the effect of clean energy investment on financial development, environmental sustainability, and economic growth. Focusing on China from 1970-2016, the study adds manufacturing value added and urbanization as moderating variables. Using advanced methods of time series econometrics, such as structural break unit root tests and fixed-effects multiple regression outputs (including FMOLS, DOLS, and robust least squares regressions), the analysis estimates long-run relationships. Using CO₂ emissions, ecological footprint, and economic growth as dependent variables, and with clean energy investment and financial development as crucial dependent factors, the study provides comprehensive evidence.

Amid increasing environmental pressures linked to economic growth, the importance of eco-innovation and green investment in mitigating carbon emissions is increasingly highlighted in recent literature. (Temesgen Hordofa et al., 2023) They are looking into the effects of eco-innovation and green investment on CO₂ emissions. Focusing on China, in particular, the study is using a national time series framework spanning the years 1990-2019. Using the Autoregressive Distributed Lag (ARDL) method, the analysis captures both the short-run and long-run effects. Using CO₂ emissions as a dependent variable and eco-innovation and green investment as key explanatory variables, eco-innovation is operationalized in the era of environment-related technology and patent indicators. The empirical findings confirm a large negative effect of eco-innovation on CO₂ emissions. Similarly, green investment is helping to make inroads toward cutting emissions in the long run. The results

show that innovation-based environmental strategies are effective in reducing environmental degradation and in examining the critical challenge of sustainable growth. Recent research is placing greater emphasis on the interrelationships among institutional performance, digital governance, and green finance in mitigating environmental degradation and examining the impact of institutional quality, digital governance, and green finance on environmental performance. Focusing on the expanded BRICS nations, this study adopts a cross-country perspective to accommodate a variety of institutional and economic contexts. With three different regression models, the analysis determines the ecological effect of carbon dioxide and nitrous oxide emissions. Using environmental performance as the dependent variable and institutional performance, digital governance, and green finance as explanatory factors, the study identifies key factors in emissions reduction. The findings indicate that improved digital governance plays a major role in reducing emissions and encouraging environmentally friendly practices. Similarly, green finance is demonstrating a net positive effect on the reduction of emissions, highlighting its role in financing sustainable technologies. The findings also show that the strengthening of institutions is an important key to reconciling economic growth with environmental conservation. From a policy perspective, the study suggests comprehensive strategies with a combination of green finance, good institutions, and digital infrastructure to achieve sustainable development. Additionally, in the future, research is invited to examine the effects by sector, as well as the long-term dynamics, of such mechanisms to inform policy formulation. Looking at the new challenges of environmental sustainability and financial integrity, the latest area of research has been gaining more and more light on the perils of green finance-related crimes in emerging economies. (Sihabudin et al., 2024) is examining the prevalence and control of green finance crimes in Indonesia. Focusing on Indonesia as a case study, the research examines illegal activities such as unauthorized forest clearing, plantation exploitation, and mining

associated with money laundering. Adopting a juridical-normative methodology, the research evaluates legal frameworks and implementation mechanisms. Using Green finance, crime, and environmental degradation as the basic variables, the analysis identifies the gaps in traditional legal instruments. Examining the role of sustainable finance in corporate governance. In recent years, research has become more specific in investigating the role of sustainable finance and how green finance practices have affected corporate governance and strategic decision-making within organizations. (Prianyshnykova & Korolenko, n.d.) They are viewing green finance as an important indicator of modern corporate governance. The study's methodology is conceptual and analytical, based on an evaluation of the integration of environmental considerations into corporate financial strategies. Using the adoption of green finance and the effectiveness of corporate governance as fertile ground constructs, the research emphasizes the instrumentality of sustainable financing in terms of transparency, risk management, and the creation of long-term value. The results show that implementing green finance mechanisms increased the corporation's accountability and ensured that the corporate organizational strategy was aligned with the goal of environmental sustainability. Additionally, future research is encouraged to delve deeper into empirical evidence across industries and countries to understand better the impact of green finance on corporate performance and sustainability outcomes. Examining the transition to sustainable energy all over the world, the importance of green finance to distributed renewable energy production is becoming more and more the focus of research. (Alharbi et al., 2023) is looking at the influence of green finance, specifically green bonds, on renewable energy development. Covering a sample of 44 countries over the period 2007-2020, the study adopts a cross-country perspective to capture heterogeneous effects. Employing sophisticated econometric methods, such as common correlated effects pooled (CCEP) estimators and structural breaks robustness tests, the analysis guarantees reliable long-run estimates.

Taking renewable energy production as an outcome measure, with green finance issuance, technology, and emissions intensity as explanatory factors, the study identifies factors critical to clean energy growth. The results show that the green finance sector plays an important role in increasing renewable energy production, with the impact greater for bonds used to fund alternative energy projects. Additionally, technological capacity is amplifying the positive impact of green finance, particularly for countries with high emissions, high climate exposure, and well-developed credit markets. The results also indicate that the effects are more pronounced for countries with net-zero emission targets and post-Paris Agreement commitments. From a policy perspective, the study highlights the importance of supporting green finance instruments and providing technical and technological certainty to maximize the benefits of renewable energy. Furthermore, future research is encouraged to examine sector-specific impacts and the interplay between policy frameworks and the efficacy of green finance. As the transition to sustainable energy unfolds worldwide, the importance of green finance for distributed renewable energy production is increasingly a focus of research. (Alharbi et al., 2023) is looking at the influence of green finance, specifically green bonds, on renewable energy development. Covering a sample of 44 countries over the period 2007-2020, the study adopts a cross-country perspective to capture heterogeneous effects. Employing sophisticated econometric methods, such as common correlated effects pooled (CCEP) estimators and structural breaks robustness tests, the analysis guarantees reliable long-run estimates.

The results also indicate that the effects are more pronounced for countries with net-zero emission targets and post-Paris Agreement commitments. From a policy perspective, the study highlights the importance of supporting green finance instruments and providing technical and technological certainty to maximize the benefits of renewable energy. Furthermore, future research is encouraged to examine sector-specific impacts and the interplay between policy frameworks and the efficacy of green finance. Amid the world's efforts

to shift to sustainable energy, recent studies have highlighted the growing interest in the role of green finance in the sustainable production of renewable energy. Alharbi et al. (2023) explore the role of green finance, specifically green bonds, in the development of renewable energy. Covering a sample of 44 countries over the period 2007 - 2020, the study takes a global perspective to capture cross-country variation. Using enhanced econometric techniques, such as the common correlated effects pooled (CCEP) estimator and robustness checks for cross-sectional dependence and structural breaks, the analysis yields robust long-run findings. Using renewable energy production as the dependent variable but taking green finance issuance, technological capacity, emissions intensity, and credit market development as explanatory factors, the study finds vital determinants of the clean energy expansion. The results show that green finance has had a significant impact on increasing renewable energy production, achieved through bonds issued for alternative energy projects. A stronger impact can be observed on bonds issued for alternative energy projects. Additionally, the current base of technology capacity is helping to increase the impact of green finance, especially in countries with higher emissions and greater exposure to climate change. The results also show an increased long-run effect in countries with low- or net-zero-emission targets and commitments after the Paris Agreement. From a policy perspective, the study recommends favoring the promotion of green finance instruments and investing in technological readiness to maximise renewable energy outcomes. Furthermore, future research is encouraged to focus on sector-specific impacts and the interplay between regulatory frameworks and the effectiveness of green finance. Possible environmental consequences of economic and energy activities. The new research heavily focuses on the determinants of CO₂ emissions in emerging economies. Caglar et al. (2022). We are exploring the role of trade openness, economic complexity, natural resources, and public-private partnerships in shaping environmental quality. Focusing on BRICS countries during 1990-2018, this study adopts a panel data approach to account

for country heterogeneity. By using second-generation panel estimation methods, the analysis accounts for cross-sectional dependence and dynamic interactions between them, making the results more robust than those obtained with first-generation models. Using CO₂ emissions as the dependent variable and economic growth, trade openness, economic complexity, natural resources, and partnership investment as explanatory variables, the study assesses key drivers of environmental outcomes. The results show that openness to trade and economic complexity contribute positively to environmental quality, while economic growth, natural resources, and public-private partnerships contribute to environmental degradation. The results add to the suggestion that the impact of partnerships and resource exploitation should be carefully regulated. From a policy perspective, the study suggests policies on improving environmental quality through sustainable trade, investment in clean technologies, and balanced economic planning. Additionally, future research is called for to examine sector-specific impacts and the interaction between the economic complexity mix and environmental performance in other emerging markets.

In the global search for sustainable economic development, recent research has focused on the role of green finance in promoting green economic growth. (Hussain et al., 2025) This study explores the link between green finance and green economic growth, as well as the moderating role of environmental governance. Focusing on G-20 countries throughout the study period 1995-2021, this study adopts a panel data approach to capture cross-country variation and long-term trends. Using secondary data from panels and statistical tests, the research addresses the role of governance mechanisms with respect to the efficiency of green finance. Using green economic growth as a dependent variable and key explanatory and moderating variables of green finance, environmental governance, and energy productivity, the dependent variable is the driving force of sustainable economic transitions.

The findings indicate that green finance significantly promotes green economic growth

through optimal resource use, energy efficiency, and environmentally sustainable investments. However, the results further indicate that potentially stringent or inefficient environmental governance can have a negative moderating effect on the impact of green finance, thereby reducing its effectiveness. From a policy perspective, the study emphasises the importance of transparent, efficient governance mechanisms and supportive policies to maximise the benefits of green finance. What is more, future research is encouraged to examine sector-specific governance effects and cross-country policy designs to enhance sustainable development outcomes—examining the key role of sustainable finance in catalyzing the transition to renewable energy. Research in sustainable finance is increasingly looking at mechanisms to encourage green investment. (Taghizadeh-Hesary, 2020) is Sustainable Solutions for Green Financing and Investing in Renewable Energy Projects. The study is taking a conceptual and policy-based approach, examining issues of financing instruments, investment structures, and community-based mechanisms. Using the constructs of green finance, green credit guarantees, renewable energy projects, and community trust, the research identifies key drivers of the mobilization of private and public capital. The findings reveal that the green credit guarantee schemes and community-based financing mechanisms have increased investment in renewable energy and mitigated the financial risks for sustainable energy adoption. The study further points out that trust and institutional support are also critical to scaling green investments in emerging markets. From the policy front, work is being recommended on the design and implementation of specific types of green financial instruments, such as risk sharing and other forms of incentives for the promotion of renewable energy development. On top of this, there is a need for future research to measure the success of specific financial instruments across different countries and types of renewable energy to improve policy and investment frameworks. As the importance of sustainable finance grows, recent studies tend to be less scientific in addressing green finance and its economic impact

on companies and capital markets. (Liu & Wu, 2023) We are reviewing the literature on green finance, sustainability disclosure, and their impact on financial performance. Conducting a systematic literature review based on the SALSA (Search, Appraisal, Synthesis, and Analysis) framework, the study analyzes the publications in the worldwide context over the last few decades. Using green finance adoption, the disclosure of sustainability, and firm financial performance and cost of capital as fundamental constructs, the study aims to synthesize empirical and conceptual evidence. The findings reveal that, in general, firms with strong green practices tend to have better financial performance and a lower cost of capital. In addition, green finance is improving risk management and the overall development of the economy. The review goes on to highlight ongoing challenges to sustainability disclosure, including inconsistency, incomparability, and assurance that may constrain the efficiency of green financial instruments. From a policy perspective, the study highlights the importance of standardized reporting frameworks and regulatory guidance to enhance the outcomes of green finance. Additionally, specific sectors affecting green finance, the integration of ESG metrics, and the long-term economic impacts of green finance globally are encouraged for future research.

Taking a look at the critical role that environmental governance plays in achieving sustainable development is an issue that has increasingly received attention in analyzing the impact of green governance and green finance policies on ecological achievements and public health. (Xu & Zhu, 2022) We are researching the effects and the relationship between green governance efficiency and green finance on sustainable environmental management. Focusing on different parts of China during the period 2008 to 2018, the research takes a provincial panel data view in order to capture regional heterogeneity. Using panel data estimation techniques, the study examines the role of green governance, green finance, and financial inclusion on environmental outcomes. Using environmental pollution, CO2 emissions, and green investment projects as dependent variables, the study examines factors

related to green government indices and green finance policies and identifies the key sustainability drivers. The results indicate that better green governance and green finance policies reduce environmental pollution. Moreover, financial inclusion has a positive impact on reducing CO₂ emissions and also on investing in green projects, which helps to strengthen sustainable development. The findings also highlight that stronger governance and financial capabilities are better positioned to establish environmental security measures. From a policy perspective, the study recommends that green finance products be scaled up, the capacity of financial institutions to offer green credit be strengthened, and green governance initiatives be encouraged. The research emphasizes the importance of coordinated policies to achieve the Sustainable Development Goals while minimizing procedural risks. In addition, the research suggests that policymakers should encourage green spending and support.

Looking at the nexus between economic growth, renewable energy, and carbon emissions, recent studies point to a multidimensional relationship among GDP, energy consumption, globalization, and climate change. (Mirziyoyeva & Salahodjaev, 2023) Investigating the influence of renewable energy, economic growth, and globalization on the level of CO₂ emissions for highly globalized countries. The analysis, which focuses on the top 50 most globalized countries between 2000 and 2018, uses a dynamic panel data approach to capture heterogeneity across countries and over time. Using two-step system GMM-type estimators, the analysis addresses potential endogeneity, heteroskedasticity, and high correlation among the lagged dependent variables. Using CO₂ Emissions as the dependent variable and GDP per capita, the proportion of renewable energy, globalization, and women's representation in parliament as explanatory variables, the study explores the drivers of environmental outcomes. The results show that renewable energy and globalization have a significant impact on reducing CO₂ emissions. In contrast, GDP per capita has an inverse U-shaped relationship with them, thereby verifying the Environmental Kuznets

Curve hypothesis. Further, the more women are represented in politics, the lower CO₂ emissions are, highlighting the role of inclusive governance in environmental management.

Examining the environmental and policy challenges of sustainable energy transitions. Recent research investigates the impact of renewable energy, policy uncertainty, and corruption on CO₂ emissions (Sadiq et al., 2024). Renewable energy consumption and policy uncertainty, corruption control, and carbon emission in BRIC-1 countries: Nexus. Focusing on four countries, Brazil, Russia, India, and China, between 1990 and 2020, to capture long-run and cross-country dynamics, the study takes a panel data approach: Using the cross-section augmented ARDL (CS-ARDL) methodology, the analysis addresses endogeneity, heterogeneity, and cross-sectional dependence issues to ensure robust estimation. Using CO₂ Emissions as the dependent variable and renewable energy consumption, policy uncertainty, and corruption control as the explanatory variables, this research tests the Environmental Kuznets Curve (EKC) hypothesis for BRIC nations 1. The results show that both the consumption of renewable energy and the effective control of corruption play important roles in reducing long-term CO₂ emissions and advancing the Sustainable Development Goals. In contrast, policy uncertainty is reported to threaten environmental sustainability, highlighting the importance of stable, predictable regulatory environments. The results further show that the BRICS-1 nations have the opportunity to apply the EKGC theory and can strike a balance between economic growth and environmental quality. From a policy perspective, the study recommends strengthening anti-corruption policies, reducing policy uncertainty, and implementing stringent environmental policies. In addition, as a strategy for the ecological sustainability of the conditions, investments in promoting renewable energy are emphasized. The link between joint governance and energy policies is identified as important for decreasing emissions in the long term, the research shows. Future research is encouraged to discuss sector-specific policy interventions and the role of

institutional quality in supporting green energy transitions.

Theoretical Background

Green Finance and CO₂ Emissions

Green finance is a form of financial investment focused on sustainable development, renewable energy sources, energy efficiency, and environmentally friendly technologies. The Sustainable Finance Theory argues that allocating capital to sustainable projects that promote clean production, technological development, and reduced dependence on fossil fuels will lead to a cleaner environment. Green bonds, green loans, and climate funds also support low-carbon infrastructure, thereby reducing carbon emissions.

Renewable Energy and CO₂ Emissions

The Energy Transition Theory implies that replacing fossil fuels with renewable energy

sources (solar, wind, hydro, biomass) will lead to a considerable decrease in carbon emissions. Renewable energy substitutes for carbon-intensive energy sources, reducing total greenhouse gas emissions.

GDP and CO₂ Emissions (Control Variable)

GDP is an indicator of an economy's growth. According to the Environmental Kuznets Curve (EKC) theory, Industrialization leads to higher CO₂ emissions in the initial stages of economic progress. Later in life, emissions decreased as economies adopted cleaner technologies and environmental policies. The control of GDP is based on the fact that economic activity directly affects energy consumption and emissions.

Variables Description

Variables and it's measurements		
Variable	Proxy	Source Data
Green Finance	Renewable energy consumption (% of total final energy consumption).	WDI
Co2 emission	Carbon dioxide (CO2) emissions (total) excluding LULUCF (% change from 1990)	WDI
GDP growth	GDP growth (annual %)	WDI
Energy Intensity	Renewable electricity output (% of total electricity output)	WDI

Research Methodology

This study will use a quantitative, explanatory design, relying on secondary panel data from 2013 to 2024. The paper examines the relationships among economic growth, CO₂ emissions, renewable energy use, energy intensity, and green finance across selected nations. The study will

attempt to establish the relationship between sustainability-related variables and macroeconomic performance using econometric techniques. It is a comparative design that will juxtapose results across different regions and explanatory, in that it seeks to identify causal relationships between environmental and

economic indicators. The sample consists of 28 countries, purposely selected from the regions identified in WDI. These are Afghanistan, Algeria, Bahrain, Bangladesh, Bhutan, Canada, Djibouti, Egypt, India, Iran, Iraq, Israel, Jordan, Lebanon, Libya, Maldives, Malta, Morocco, Nepal, Oman, Pakistan, Qatar, Saudi Arabia, Sri Lanka, Syria, Tunisia, United Arab Emirates, and the United States. The choice was made based on the availability of data, its relevance to renewable energy and sustainability, and its representation of the region. Such a purposive sample then makes it possible to conduct meaningful cross-country comparisons and point out the distinctions between energy transition pathways.

To define abstract concepts in the study, proxies commonly used in the empirical literature are employed. Renewable energy consumption as a percentage of total final energy consumption is a proxy of green finance because the level shows how much economies are allocating resources towards sustainable energy. Renewable electricity production is a proxy for energy intensity, expressed as a percentage of overall electricity production, and represents the efficiency and sustainability of power generation. Annual GDP

growth rates, a traditional macroeconomic indicator, also measure economic growth. CO₂ emissions are used as a proxy for environmental sustainability, which is the ecological footprint of economic activity. Such proxies are defensible since they are standardized, cross-country, and consistent with previous sustainability and growth literature.

To define abstract concepts in the study, proxies commonly used in the empirical literature are employed. Renewable energy consumption as a percentage of total final energy consumption is a proxy for green finance, as the level indicates how much economies allocate resources to sustainable energy. Renewable electricity production is a proxy for energy intensity, expressed as a percentage of overall electricity production, and represents the efficiency and sustainability of power generation. Annual GDP growth rates, a traditional macroeconomic indicator, also measure economic growth. CO₂ emissions are used as a proxy for environmental sustainability, which is the ecological footprint of economic activity. Such proxies are defensible since they are standardized, cross-country, and consistent with previous sustainability and growth literature.

Table 1: Descriptive Statistics

<i>Variable</i>	<i>Obs</i>	<i>Mean</i>	<i>Std.Dev.</i>	<i>Min</i>	<i>Max</i>
<i>CO₂emission</i>	560	247.5174	316.4437	-56.11676	2218.288
<i>Green finance</i>	560	17.10692	23.74743	34	92
<i>GDP growth</i>	560	3.680061	7.225201	-50.33852	86.82675
<i>Energy intensity</i>	560	19.00397	29.5881	0	100

The average CO₂ emission was 247.5 metric tons, and the standard deviation was large (Std. Dev. = 316.4), suggesting substantial variation in CO₂ emissions across countries and years. The average share of green finance was 17.1 percent of total energy consumption, with some countries having 0 percent, indicating unequal use of renewable energy. The GDP growth was around 3.68; it was

volatile (maximum up to -50% and maximum up to +86%). The average intensity of energy was 19, and the highest energy intensity stood at 100, which implies the presence of severe differences in the levels of efficiency. These descriptive findings demonstrate the heterogeneity of the sample; hence, the use of regression analysis to reflect systematic associations.

Table 2: Correlation Analysis

<i>CO₂emission</i>	Coef.	Std. Err.	t	p> t	[95% Conf.	Interval]
<i>Green finance</i>	2.5609	.9184933	2.79	0.005	.7567589	4.365041
<i>GDP growth</i>	2.823472	1.810847	1.56	0.120	-.7334659	6.38041
<i>Energy intensity</i>	.5147217	.7350382	0.70	0.484	-.9290696	1.958513
<i>cons</i>	183.537	17.17824	10.68	0.000	149.7938	217.2782
	<i>CO₂emission</i>	<i>Green finance</i>	<i>GDP growth</i>	<i>Energy intensity</i>		

CO ₂ emission	1.0000			
Green finance	0.2358	1.0000		
GDP growth	0.086	0.0788	1.0000	
energy intensity	0.2032	0.8002	0.0202	1.0000

There was a moderate positive relationship between CO₂ emissions and green finance (0.236) and energy intensity (0.203), but not between CO₂ emissions and GDP growth (0.081). It is also noteworthy that the measures of green finance and energy intensity were highly correlated ($r = 0.800$),

implying that countries investing in renewable energy sources are more likely to report higher energy intensity. These findings provide preliminary evidence for H1 and H3, whereas H2 appears weaker at the level of correlation.

Table 3: Regression Analysis

	<i>SS</i>	<i>Df</i>	<i>Ms</i>
<i>Model</i>	337469.1	3	1124897.25
<i>Residual</i>	52601669.7	556	94607.3196
<i>Total</i>	55976361.5	559	100136.604

The standard regression model (Result 3) showed a positive and statistically significant influence of green finance on CO₂ emissions (Coef. = 2.56, p = 0.005), which rejected H1 but in a counterintuitive manner, in that the greater the green finance, the greater the CO₂ emissions. The positive effect on GDP growth was positive but insignificant (Coef. = 2.82, p = 0.120), which

weakly supports H2. Energy intensity was also positive but not significant (Coef. = 0.51, p = 0.484), and thus could not support H3. These results were verified in the strong regression (Result 4): green finance remained important (p < 0.001), whereas GDP growth and energy intensity were not significant.

Table 4: Log-Transformed Regression

<i>CO₂ emission</i>	<i>Coef.</i>	<i>Robust Std.</i>	<i>t</i>	<i>P> t </i>	<i>[95% Conf.</i>	<i>Interval</i>
<i>Green finance</i>	2.5609	.7238772	3.54	0.000	1.139032	3.982768
<i>GDP growth</i>	2.8234427	2.64234	1.07	0.286	-2.366717	8.013662
<i>Energy intensity</i>	.5147217	.5238951	0.98	0.326	-.5143338	1.543777
<i>-Cons</i>	183.536	17.36611	10.57	0.000	149.4248	217.6472

<i>Inco2</i>	<i>Coef.</i>	<i>Robust Std.</i>	<i>t</i>	<i>P> t </i>	<i>[95% conf.</i>	<i>Interval]</i>
<i>Green finance</i>	.0204191	.0027504	7.42	0.000	.0150155	.0258226
<i>GDP growth</i>	.0101142	.007445	1.36	0.175	-.0045127	.0247412
<i>Energy intensity</i>	-.0071348	.0024357	-2.93	0.004	-.0119201	-.0023495
<i>-cons</i>	4.841533	0.673262	71.91	0.000	4.70926	4.973806

The log regression (Result 5) strengthened the evidence: green finance remained positive and highly significant (Coef. = 0.020, p < 0.001), GDP growth was positive but insignificant (Coef. = 0.010, p = 0.175), while energy intensity turned negative and significant (Coef. = -0.007, p =

0.004). This suggests that while green finance is associated with higher emissions (possibly due to transitional reliance on mixed energy sources), improvements in energy efficiency (lower intensity) significantly reduce emissions, thereby partially supporting H3 in the transformed model.

Table 5: Multicollinearity Test (VIF)

<i>Variable</i>	<i>VIF</i>	<i>1/VIF</i>
<i>Green finance</i>	3.06	0.326280
<i>Energy intensity</i>	3.05	0.327645
<i>GDP growth</i>	1.01	0.989549

Mean VIF

2.38

VIF values were significantly below the crucial threshold of 10, with a mean of 2.38 and a range of 1.01 to 3.06. This demonstrates that multicollinearity is not a significant issue and that the regression's findings are trustworthy.

Conclusion and Recommendations

According to the study, green finance has a complex but considerable impact on environmental results. First, using more renewable energy can coexist with fossil fuel use, even if it temporarily raises CO₂ emissions. This emphasizes how long-term policy frameworks are essential for successful decarbonization. Economic development may not be the primary driver of environmental deterioration, even though GDP growth and emissions have a positive but non-statistically significant relationship. This casts doubt on conventional wisdom on the trade-off between growth and emissions and raises the possibility of decoupling the two in specific situations. When adequately modeled, energy intensity became a crucial factor, and the log-transformed regression confirmed that it had a large and negative impact on emissions. This demonstrates the significance of increasing efficiency to reduce environmental impacts. The study comes to the conclusion that although green finance is crucial, complementing actions like energy efficiency and structural changes to energy systems are necessary for it to be effective. Taken together, the findings add to the body of knowledge on sustainability by showing that financing, growth, and efficiency interact in intricate ways and that, to achieve significant carbon reductions, policy interventions must be tailored to local settings.

To improve sustainability results, several recommendations are put out in light of the findings. The first step in preventing transitional increases in emissions is for policymakers to ensure that green money is allocated to projects that actually replace fossil fuels rather than coexist with them. Second, since lowering energy intensity is an efficient way to reduce emissions, governments should prioritize energy-efficiency

initiatives. Third, international institutions should help poor nations increase their capacity to accept renewable energy sources and raise their efficiency standards. Fourth, sustainability concepts should be incorporated into economic growth plans to make sure that expansion does not conflict with environmental objectives. Fifth, systems for tracking and evaluating the success of green finance initiatives need to be put in place. Sixth, support regional collaboration to share best practices in the implementation of renewable energy, especially in South Asia and North Africa. Seventh, to hasten transitions, developed nations such as the United States and Canada ought to offer technologies to emerging nations. The eighth step is to increase data availability and transparency to enable robust econometric analysis and policy planning. Finally, governments ought to encourage private-sector involvement in green financing to increase investment pools.

Tenth, to ensure coherence, energy policies ought to align with the SDGs' climate pledges. Eleventh, awareness-raising initiatives must be started to encourage businesses and households to utilize energy efficiently. Twelfth, to bring market behavior into line with sustainability objectives, fiscal incentives such as renewable energy subsidies and fines for excessive emissions should be implemented. Thirteenth, to improve affordability and efficiency, research and innovation in renewable technology should be encouraged. Fourteenth, planning for long-term sustainability should incorporate both environmental and economic factors. Finally, to achieve long-term reductions in CO₂ emissions, policymakers must acknowledge that green finance alone is not enough and must be combined with structural reforms, efficiency improvements, and international collaboration.

REFERENCES

- Brida, J. G., Alvarez, E., Cayssials, G., & Mednik, M. (2024). How does population growth affect economic growth and vice versa? An empirical analysis. *Review of Economics and Political Science*, 9(3), 265-297.

- Suhatman, A. S., & Aimon, H. (2024). Interlinkages between environmental quality, economic growth, and human capital in Indonesia: Implications for sustainable development policies. *Challenges in Sustainability*, 12(3), 190–202.
- Alharbi, S. S., Al Mamun, M., Boubaker, S., & Rizvi, S. K. A. (2023). Green finance and renewable energy: Worldwide evidence. *Energy Economics*, 118, 106499.
- Caglar, A. E., Zafar, M. W., Bekun, F. V., & Mert, M. (2022). Determinants of CO2 emissions in the BRICS economies: The role of partnership investment in energy and economic complexity. *Sustainable Energy Technologies and Assessments*, 51, 101907.
- Hussain, A., Alim, W., Tariq, A. R., Fazil, M. T., & Khan, J. (2025). Nexus Between Green Finance & Green Economic Growth in G-20 Economies: Moderating Role of Environmental Governance. *Journal of Asian Development Studies*, 14(2), 135–147.
- Ng, A. W. (2018). From sustainability accounting to a green financing system: Institutional legitimacy and market heterogeneity in a global financial centre. *Journal of Cleaner Production*, 195, 585–592.
- Liu, C., & Wu, S. S. (2023). Green finance, sustainability disclosure, and economic implications. *Fulbright Review of Economics and Policy*, 3(1), 1–24.
- Wu, Y. (2024). Analysis on the relationship among green finance, government environmental governance, and green economic efficiency: evidence from China. *Frontiers in Environmental Science*, 12, 1476141.
- Taghizadeh-Hesary, F., & Yoshino, N. (2020). Sustainable solutions for green financing and investment in renewable energy projects. *Energies*, 13(4), 788.
- Martin, P., & Camerone, G. (2025). Green Economic Growth and Environmental Governance: A Panel Analysis of G-20 Countries. *Journal of Energy and Environmental Policy Options*, 8(3), 17–27.
- Xu, S., & Zhu, H. (2022). Do green governance efficiency and green finance policies matter in a sustainable environment: Implications for public health? *Frontiers in Public Health*, 10, 861349.
- Waheed, R., Chang, D., Sarwar, S., & Chen, W. (2018). Forest, agriculture, renewable energy, and CO2 emission. *Journal of Cleaner Production*, 172, 4231–4238.
- Prianyshnykova, M., & Korolenko, M. «GREEN» FINANCE AS A MARKER OF MODERN CORPORATE GOVERNANCE.
- Zahoor, Z., Khan, I., & Hou, F. (2022). Clean energy investment and financial development as determinants of environment and sustainable economic growth: evidence from China. *Environmental Science and Pollution Research*, 29(11), 16006–16016.
- Bonsu, M. O. A., Wang, Y., Nartey, P. R. D., & Amala, M. N. (2025). Does the integration of Fintech and green finance enhance sustainability performance in the banking sector? Information technology governance as a moderator. *Business Strategy and the Environment*, 34(8), 9954–9977.
- Bouyghrissi, S., Murshed, M., Jindal, A., Berjaoui, A., Mahmood, H., & Khanniba, M. (2022). The importance of facilitating the renewable energy transition to abate CO2 emissions in Morocco. *Environmental Science and Pollution Research*, 29(14), 20752–20767.
- Razmjoo, A., Kaigutha, L. G., Rad, M. V., Marzband, M., Davarpanah, A., & Denai, M. J. R. E. (2021). A Technical analysis investigating energy sustainability utilizing reliable renewable energy sources to reduce CO2 emissions in a high-potential area. *Renewable Energy*, 164, 46–57.
- Steuer, S., & Tröger, T. H. (2022). The role of disclosure in green finance. *Journal of Financial Regulation*, 8(1), 1–50.