Prague Economic Papers
2024, Volume 33, Issue 5
https://doi.org/10.18267/j.pep.876

PRAGUE UNIVERSITY OF ECONOMICS AND BUSINESS

Impact of Green Finance on High-Quality Economic Development: A Panel Data Regression

Zhao Liang, Ellisha Nasruddin

Graduate School of Business, University Sains Malaysia, Penang, Malaysia,
email: zhaoliang729@126.com

Abstract

Green finance aims to achieve a balance between economic performance and sustainable economic development. This study examines the effect of green finance on sustainable economic development at the national level by spotlighting countries that are at the forefront of green bond issuance. Employing balanced panel data and utilizing a mediation model with fixed effects, the results demonstrate a significant ability of green finance to mitigate carbon emissions and promote high-quality economic development. The robustness of the findings is confirmed by a series of statistical tests. Furthermore, the renewable energy consumption structure enhances the suppressive effect of green finance on carbon emissions, highlighting its crucial role as a channel for mitigating carbon emissions. Overall, increasing green bond investment and structuring renewable energy consumption are crucial for carbon emission reduction, and this paper contributes new evidence regarding the emission reduction effects of green finance. It also offers several policy implications: by prioritizing green finance, R&D, and renewable energy consumption, the policymakers can achieve high quality economic development and lower carbon emissions.

Keywords: carbon emission; green finance; renewable energy consumption; mediation model

JEL Classification: Q56, G23, Q43

1. Introduction

The environmental concerns are growing, and pollution and climate change are among the two most common outcomes of how economies as well as technologies are developing. Finding a balance between ecological sustainability and economic prosperity has become more

significant globally and it aligns with the sustainable economic development goals. High-quality, high-speed, open, and inclusive development (HQED) is a concept that highlights the necessity of finding a balance between speed and quality in economic development when seen through the scope of the new development paradigm (Liu and Li, 2024). It is characterized by development that is inclusive, coordinated, green, and open. Most of the developed and developing economies have shifted their focus from high-speed economic growth to high-quality and sustainable economic development. From a resource investment point of view, "green development" is defined as producing the highest economic output with the lowest ecological impact (Slazar, 1998). As a result, it offers an objective depiction of the degree of sustainable economic growth. Achieving green development, nevertheless, requires identifying and securing funding sources and their subsequent effective utilization.

Green development is one of the most important components of transition to a new stage of sustainable development. The creation of novel financial mechanisms and eco-friendly financial assets benefits environmental sustainability and green development. Green finance offers strategic ways to lower climate risk and enhance environmental quality (Nawaz et al., 2021). With the ultimate goal of enhancing the ecological environment and reducing the environmental impact of industrial production, green finance actively promotes the growth of green industries as well as the technological modernization and green transformation of traditional businesses. Therefore, green finance both generates financial gains and preserves the environment. Growing concerns over environmental preservation and climate change in many nations gave rise to the concept of "green finance," a financial innovation that facilitates the shift to green economy (Yang, 2023). Because it connects the financial sector, environmental improvement, and economic growth, green finance may not only help to conserve the environment but also improve our future. Therefore, it is essential to test the association between green finance and high-quality economic development empirically for different economies around the world. With this in mind, the presented study focuses on estimating the relationship between green finance and high-quality economic development for the top 11 green bond-issuing countries.

Considerable research has been done on the connection between green finance and HQED. While many academics are of opinion that green finance can enhance HQED, other researchers think that the connections between green finance and HQED are more nuanced. Green funding is essential for advancing environmental protection efforts, fostering scientific and technical innovation, and raising the bar for regional economic development (Su et al., 2019). An important consideration when assessing the country's environmental conditions is green financing. The quality of the environment rises in tandem with the improvement in financial development levels. Green finance facilitates the growth of the green industries and develops

the local economy by raising awareness of green development concepts and promoting innovative financial services. Nonetheless, some academics contend that green financing achieves more than just aid to HQED. The extent to which green finance is developed and the efficiency with which green financial resources are allocated may eventually affect macroeconomic stability and growth in the long run (Ning and She, 2014). Existing literature reveals varying conclusions on the association between green finance and HQED, and these relationships are dissimilar across different regions. Hence, there is a need for comprehensive cross-country analysis that takes the varying levels of green finance into account while estimating the effect of the adoption of green finance on the environment and overall economic outcomes. This study offers significant policy implications and aims to fill the existing research gap using a panel data approach to robustly assess the complex associations between green finance, renewable energy consumption and other macroeconomic variables. Its significance and uniqueness lies in two things: first, it examines the underlying relationship using panel data at cross country level, thereby expanding the existing literature; and second, it incorporates renewable energy consumption (REC) as the mediating variable to evaluate the relationship between variables of interest.

2. Literature Review

2.1 Theoretical review

A financial tool that incorporates the ideas of environmentally friendly development is known as green finance (GF). Advancements in green finance facilitate the development of high-quality production companies and investment in environment-friendly technologies. This stems from the GF's crucial role in capital provision, investment fostering, the regulation of green initiatives, and risk distribution. It is also able to control business practices, encouraging the use of green capital for improving the integration of green technology development, creating environmentally conscious business practices, and causing a gradual shift towards green economy (Gill et al., 2018). This, in turn, induces high-quality economic development while also fostering a balance between economic growth and environmental improvement. GF is referred to as a financial tool that actively promotes and incorporates methods of green development. Among its core tasks are the facilitation of capital funding, encouragement of innovation, ensuring green oversight, and lowering risk. The development of GF can have a significant effect on high-quality production firms by encouraging scale effects through the provision of financial support for the evolution of innovative and environment-friendly production methods. It also serves as an effective "capital pool" for businesses producing environmentally friendly products (Jiang

et al.,2018). This money, in turn, can be used by these firms to promote initiatives that lower pollution while restoring the environment which continuously boosts positive environmental effects of economic growth and promotion of high-quality development.

The banking sector and other financial institutions can send effective signals to the market through the implementation of policies such as limiting financial resources and raising costs for highly polluting and energy-intensive businesses. Businesses should also be compelled to share information regarding their green development projects within the green financial system (Khan et al., 2018). Furthermore, investors can allocate their resources based on the dedication of the organization to environmental practices. Such approach enables transparency and accountability in green practices while encouraging firms and industries to switch to environmentally friendly technologies, making it easier for the money to flow towards green initiatives.

2.2 Empirical research

Past studies and research state that the promotion of environmental sustainability is the core issue of green finance. This is accomplished through making investments into eco-friendly businesses and technologies or by actively aiding eco-friendly projects. In addition to exploring the direct impact of green finance on reducing CO_2 emission, this study also intends to analyze its role in indirectly affecting CO_2 through REC. The study specifically aims to discover whether the relationship between the impacts of CO_2, green finance, and the mediating variable, REC, either increases or mitigates the effects of these elements.

Factors such as GDP, FDI inflows, R&D investment, renewable energy consumption, and urbanization may seem distinct, but they all affect the environment in one or another way, and thus, are related to each other. To study these relations, various models and theories have been introduced over the years. Additionally, the dependency of economic growth on the environment and vice-versa have also been assessed. The conducted study exclusively focuses on the STIRPAT model or the "Stochastic Impacts by Regression on Population, Affluence and Technology Model", which is effective for analyzing the link between distinct factors (Lin et al., 2014). This model acts as an important link in assessing the connection between human behavior and changes in the environment. The technique's accuracy is largely influenced by the core factors including population, technology, resources, and the research setting. Different data associated with population size, wealth, technological improvements, and the growth rate are included in the model. The main motive of the study is to assess the environmental degradation stemming from deforestation or CO_2 emission. Based on the STIRPAT model and the findings of Chikaraishi et al. (2015), the paper also aims to improve the data quality and corresponding

evaluation. For this, REC is used as a mediating variable where the effect of REC on the association between CO_2 and other factors is analyzed. Furthermore, it also reveals how renewable energy affects the impact of green finance on CO_2 emissions. This, as a result, provides a crucial base for the current study, resulting in a better understanding of the connection between green finance and CO_2 emission.

2.2.1 Macro-economic variables and carbon emissions

The research on this subject has produced varying and perhaps contradictory conclusions because the relationship between economic growth and the environment is very complex. These economic indicators are frequently linked to broader measures of economic progress, and FDI and trade openness are frequently seen as key contributors to economic growth and stability. A host country's economy can profit greatly from FDI in several ways such as expanding commerce, increased capital investment, and technological transfer. However, as indicated by Xing and Kolstad (2002), it's important to understand that while FDI might induce a positive economic benefit, it can also induce negative environmental repercussions. Therefore, green finance can support inclusive economic expansion where it focuses specifically on how per capita energy use, wealth inequality, and economic growth affect environmental results. The main conclusion of the analysis is that green finance has the potential to promote inclusive economic growth. In other words, it is possible to produce economic growth that benefits a larger range of society when financial processes prioritize ecologically friendly acts. Researchers have associated FDI with several pollutants, including CO_2 emissions, suggesting that FDI may be a factor in environmental degradation. Moreover, researchers have discovered a mutually positive relationship between FDI and environmental preservation. According to Stretesky and Lynch (2009), FDI can offer environmentally friendly and effective production methods that can result in less air pollution. Merican et al. (2007) found that FDI led to higher levels of pollution in Malaysia, Thailand, and the Philippines among the ASEAN-5 economies. In the case of Indonesia, the study found that FDI and pollution depicted a negative correlation. A similar study by Atici (2012), which used data for ASEAN economies, indicated similar results regarding the relationship between FDI and CO_2 emission. However, the study failed to find any significant effect of FDI on CO_2 emission in case of the Philippines, Indonesia, Malaysia, and Thailand. The study by Hamid et al. (2012) that used the Environmental Kuznets Curve (EKC) indicated that FDI led to higher levels of CO_2 emissions both in the short and long run, hence indicating that the pollution haven hypothesis is true.

The impact of R&D investment on the quality of the environment has been a major research issue. Allevi et al. (2019) used three categories to explain the effect of trade liberalization where the trade-off between higher productivity and environmental damage is associated with this effect. According to Appiah-Konadu (2013), while productivity is boosted due to trade liberalization, there may be a rise in environmental damage at a similar rate. As a result, during the period of trade liberalization, the policymakers must promote environmentally friendly manufacturing practices and technologies with the focus on production techniques and technology. Grossman and Krueger (1995) highlight that this effect is associated with the modifications in the economic structure stimulated by trade liberalization. It implies that the economy's structure is changing, possibly leading to a stronger emphasis on innovative technologies or tertiary industries, with implications for environmental impact. According to Onder (2012), as trade liberalization increases people's incomes, they tend to favor ecologically friendly goods. In addition, Mujtaba et al. (2022) found that in upper-middle-income nations, there was low correlation between trade openness and CO_2 emissions.

Regarding the impact of trade openness on environmental quality, the literature, however, offers conflicting conclusions. The EKC theory has also attracted great attention within academic studies where the complex relation between GDP and environmental damage, which is measured using indices such as carbon, SO_2, and NO, has been the major topic taken up by researchers. However, it must be noted that different economies and environmental variables may react drastically differently in the presence of EKC and structure. With the contradictory results highlighted by mainstream studies, we underline the complexity of these interactions with the following hypothesis.

H1: Macro-economic variables attributed to economic development have a significant impact on CO_2

2.2.2 Green finance and carbon emissions

Green Finance and green investment are often used interchangeably. This is because it is an extensive idea covering various financial undertakings. It highlights the allocation of financial resources to environmentally friendly projects and businesses, thereby encouraging eco-friendly goods and services development, which further supports projects that promote renewable energy and develop plans to accomplish the ultimate goal of the creation of sustainable economy. The study by Gianfrate and Peri (2019) provides data on the advantages of green bonds among which is the decreasing level of carbon gases in the environment. Green finance also plays a crucial role in reducing the level of CO_2 emission by encouraging activities that aim to benefit

the environment. The study concludes that one of the important examples of financial mechanics in green bonds further encourages green activities and schemes. The purpose of these bonds is to financially help such schemes that aim to develop the environment sustainably, which includes the optimum use of renewable resources and investment in infrastructure that does not have any negative impact on the environment. Also, the study by Glomsrd and Wei (2018) states that green finance can ultimately result in a decrease in the level of carbon emission, and it favors the efficient use of renewable resources. The countermeasure adopted by many economies against the harmful effects of climate change and in order to develop a sustainable environment was the increase in the dependency on renewable resources. Under the projects of green finance, various initiatives have been taken to gradually reduce carbon emissions by financing renewable resource schemes.

2.2.3 Renewable energy consumption: a mediator

Green finance is a significant factor that helps achieving the environmental sustainability goals of nations where its motive is to invest in businesses or machinery that induce an environmental benefit while also encouraging environmentally friendly schemes. The main objective of green finance is to promote economic development and growth, while, on the other hand, minimizing the environment exploitation. Green finance is a powerful instrument as it has many advantages that ultimately result in a healthy and sustainable relationship between the economy and the environment. In today's world, there is a pressing need to pay attention to climate change and environmental exploitation which can be done by adapting and facilitating the usage of green finance. The study points out the importance of green finance in developing the economy efficiently by improving environmental conditions. It also points out the direct and indirect influence on the level of CO_2 emissions.

For one of the Chinese companies, Cheng et al. (2023) used the difference-in-differences technique to discover the connection between green finance and REC. The result discloses that green finance, directly or indirectly, can increase the application of REC accordingly. Hou et al. (2023) used 53 countries worldwide as sample and empirically tested the impact of GF on REC. The results show that GF can effectively improve the development of renewable energy, and this positive impact is even greater in developed countries, countries with higher levels of GF, and emerging economies. Bughio et al. (2023) concluded that GF can effectively increase the utilization of renewable energy, and there is a negative correlation between REC and CO_2. Mumuni and Life (2023), based on the data from 41 African countries and using GMM, empirically explored the factors influencing CO_2 emissions. The outcomes show that the REC has a long-term carbon reduction effect in Africa. Therefore, it is necessary to upgrade

Africa's current energy structure to a REC to achieve a green, low-carbon environment. Based on the above research, this study concludes that GF can mitigate CO_2 effectively, and the REC is an important channel for achieving carbon reduction (Khan et al., 2022).

Furthermore, it is often known that faster economic development is the main factor contributing to the rise in the consumption of natural resources. This development is also accountable for their rapid exploitation and the ensuing decrease in their availability (Ranđelović et al., 2020). The unrestrained pace of industrialization and the depletion of non-renewable resources, especially fossil fuels, are considered to be the primary contributors to global pollution. Sustainable development is the pursuit of the most feasible economic results while preserving the social and environmental facets of growth. Stated differently, the utilization of renewable energy is a fundamental component of sustainable economic development. Another study by Dincer (2000) highlights that the current environmental issues require long-term sustainable development strategies. One of the most economical and effective energy sources is renewable energy. Therefore, sustainable development and renewable energy are directly related. Finding sustainable energy sources, including renewable energy, should be a top priority for societies aiming for sustainable growth.

H2: GF significantly reduces carbon emissions by increasing REC, which has a significant mediating effect.

2.4 Summary and research gap

In recent decades, growth in developed and developing economies has been driven by technological advancements and industrialization, but this extensive development is coming at the expense of the environment, thereby leading to ecological degradation. By investing in green bonds, green loans, as well as other environmental projects, green finance can harmonize both ecological situation along with economic growth and development. Furthermore, it is also evident that renewable energy consumption thereby leads to lower carbon emissions, and it is an important tool for attaining long-term benefits of sustainable development. However, existing studies have only focused on theoretical approaches or limited their empirical analysis to individual economies; therefore, cross-country analysis of this issue is missing, presenting the most prominent research gap. The following analysis aims to fill this gap by estimating this relationship across 11 top green bond issuing economies to account for varying levels of green finance adoption. Furthermore, it incorporates both static and dynamic panel data analysis and its robust analytical approach is an improvement over existing methodologies, thereby making the results robust and offering valuable insights to the policymakers.

3. Data and Methodology

3.1 Data

The presented study uses data from several reputable sources such as World Bank and the International Energy Agency (IEA); it covers a diverse set of countries representing different levels of economic development as well as environmental practices between 2013 and 2020. This period is chosen because the World Bank data are provided for each country up to 2020. This study aims to investigate the direct and indirect effects of GF on CO_2, emissions, as well as the impact of a range of macroeconomic variables on carbon emissions. The country selection for this study was guided by several criteria, thereby ensuring a comprehensive analysis. Among these criteria are economic diversity, geographical representation, and data availability, as well as their relevance to green finance initiatives. First, to ensure that the sample represents a diverse range of economic development levels, the chosen countries include high-income, middle-income, as well as low-income economies. Second, the chosen economies do not belong to any specific region. It ensures geographical diversity which allows for the results to be generalized for a global context. Third, the economies chosen are actively engaged in several green finance initiatives – mainly the issuing of green bonds; and hence, the chosen sample is relevant for the estimation of the underlying relationship. According to Statista (2023), the top 11 economies in terms of green bond issuing as of 2022 are China, the United States, Germany, the Netherlands, France, the United Kingdom, Spain, Italy, Japan, Canada, and Sweden, and these are the countries included in the sample. Finally, the chosen sample is based on countries with greater green finance initiatives because data for economies with lower green bond investments were not readily available and had missing values. The key variables of interest, their abbreviations, and their descriptions are presented in Table 1. The World Bank Open Data and the World Development Indicators are the main sources of information on all dependent and independent variables. Green loan information is from the Organization for Economic Cooperation and Development. The inclusion of green finance (GF) as a core independent variable in this study, which goes beyond a conventional analysis, is intriguing. Here, green finance is captured via green bond issuances by the chosen countries. It is anticipated that GF will either enhance or dampen the environmental effects of the above-mentioned economic and energy-related variables, which makes its role in the environment crucial. The study uses a variety of metrics to quantify its important variables. The amount of inward FDI relative to GDP is used to estimate foreign direct investment (FDI). GDP per capita is calculated using constant US dollars from 2017. The percentages of the total population and total energy consumption are used to reflect urbanization and REC, respectively.

Table 1: Variable description

Variable	Variable Description	Symbol
Carbon Dioxide Emissions	Carbon emissions (metric tons per capita), Taking Natural Log	CO_2
Green Finance	Green Bond Issuances by Country in Constant 2017, Billion US Dollars, Taking Natural Log	GF
Renewable Energy Consumption	Renewable energy consumption (% of total final energy consumption)	REC
Gross Domestic Product	Gross Domestic Product per capita (constant 2017 US$), Taking Natural Log	GDP
R&D expenditure	Research and development expenditure (% of GDP)	RD
Urbanization Level (URB)	Urban population (% of total population)	URB
Foreign Direct Investment Inflow (FDI)	Foreign direct investment, net inflows (% of GDP)	FDI

Source: authors' processing

Our research aims to analyze the complex association between distinct aspects of the environment and the economy. The core aim of the empirical research is to understand the effect of green finance on carbon emission, which is one of the significant measures of environmental sustainability. The analysis also includes mediating variables such as REC, which is expected to mediate the link between the independent variables and carbon emission. The study's selection of variables indicates the commitment of the analysis to highlight the complex associations between the economic and environmental aspects of the nation. The results are expected to contribute to the existing knowledge pool on sustainability and the corresponding policy suggestions regarding green finance which can help the nations build an ecologically sustainable future.

3.2 Methodology

In the first step of data analysis, the raw data were cleaned and processed to deal with missing values, and the final dataset was created. Furthermore, it is essential to start with a correlation test and a variance inflation factor test before beginning the examination of the panel data. These initial measures are essential for avoiding spurious regression traps and ensuring the accuracy of the subsequent regression analysis. Descriptive statistics and a correlation matrix are computed for the studied variables in the early phases of the analysis. These

statistics give a thorough summary of the primary trends in the data as well as the relationships between the variables. Moreover, since the existing data has both time-series and cross-sectional elements, to estimate the underlying relationship, we employ a panel data regression model. The present study employs the Dietz and Rosa STIRPAT model (Dietz and Rosa, 1997). The primary Equations (1) to (3) depict the set of mediation effect models aimed at analyzing the associations between green finance (GF), renewable energy consumption (REC), and carbon emissions. Here, the mediator is the REC, i.e., renewable energy consumption. Looking closely, Equation (1) represents the direct effect of GF on CO_2 emissions, Equation (2) is the direct effect of green finance on renewable energy consumption (REC), and finally, Equation (3) estimates the mediation effect of REC on the association between the GF and the carbon emissions, i.e., CO_2. The equations use GDP, R&D, urbanization, and FDI as control variables and this approach helps in establishing both direct and indirect effects of green finance on carbon emissions.

$$CO_{2it} = \alpha_1 + \alpha_2 GB_{it} + \alpha_3 GDP_{it} + \alpha_4 RD_{it} + \alpha_5 URB_{it} + \alpha_6 FDI_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (1)$$

$$CO_{2it} = \beta_1 + \beta_2 GB_{it} + \beta_3 GDP_{it} + \beta_4 RD_{it} + \beta_5 URB_{it} + \beta_6 FDI_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (2)$$

$$CO_{2it} = \phi_0 + \phi_1 REC_{it} + \phi_2 GB_{it} + \phi_3 GDP_{it} + \phi_4 RD_{it} + \phi_5 URB_{it} + \phi_6 FDI_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (3)$$

The aims of this study will be fulfilled using robust fixed effects regression models to control for the unobserved heterogeneity across economies in the sample.

In this instance, i stands for particular nations and *t* for particular periods. ε_{it} refers to the error term, which takes into account random or irrational changes in the data for each nation and period. It is common practice to transform these variables by calculating their natural logarithms when using panel data regression, where different variables have different measurement scales. The challenges caused by varying units and magnitudes are addressed, which also helps to standardize the data. The fixed effects regression model is estimated from the chosen sample using the Stata software and estimation through static and robust fixed effect model enables us to evaluate the causal effect of green finance on carbon emissions both directly and indirectly through REC, since this model captures both country as well as time-specific effects.

Furthermore, to check the robustness of the analysis and the key findings, the study also employs robustness checks in the form of a dynamic panel data regression model – the generalized method of moments (GMM) model and the random effects model. The above-mentioned robustness checks confirm the stability of the benchmark regression models and help in checking whether the findings are driven by model assumptions or even data peculiarities and whether they can be generalized or not, i.e., whether the model has external validity.

4. Findings

In the first step of data analysis, the results of the estimations are discussed. The summary statistics are presented in Table 2 and the correlation analysis is in Table 3. Table 2 includes mean, median, and standard deviation, providing basic indicators of the data's central tendency and variability. The results in this table suggest that the average CO_2 emissions are 1.9907 with a standard deviation of 0.446, thereby suggesting moderate variation in the CO_2 emissions over the dataset. Further, the mean green finance indicator is 6.0192, and since its standard deviation is high, it shows high variability in the green finance initiatives undertaken by the countries in the sample.

Table 2: Results of Descriptive Statistics

Variables	Mean	Std. Dev.	Min	Max
CO_2	1.9907	0.4460	1.1765	2.7795
GF	6.0192	1.4783	2.6780	8.7093
REC	16.6276	12.1568	4.9400	58.4000
GDP	10.4693	0.4973	8.8617	11.0137
R&D	2.2759	0.7208	1.1905	3.5272
URB	80.0171	9.3267	53.0130	92.2360
FDI	2.8095	8.9034	–36.1404	43.4872

Source: authors' calculations

4.1 Multicollinearity analysis

Table 3 shifts focus to correlation coefficients, which are crucial for identifying potential linear relationships between variables. The results in Table 3 show that there is a weak negative association between CO_2 emissions and green finance, and association between CO_2 emissions and renewable energy consumption. Overall, the correlation coefficients between variables are below 0.8, thereby indicating that there is no possibility of perfect multicollinearity among the variables in the model.

Table 3: Results of Correlation Analysis

Variables	CO_2	GF	REC	GDP	RD	URB	FDI
CO_2	1.000						
GF	−0.060	1.000					
REC	−0.454	0.012	1.000				
GDP	0.160	−0.005	0.176	1.000			
R&D	0.115	0.153	0.257	0.304	1.000		
URB	0.079	0.000	0.071	0.806	0.362	1.000	
FDI	0.076	−0.066	−0.103	0.048	−0.057	0.087	1.000

Source: authors' calculations

Based on the results of the correlation analysis and to formally test the presence of multicollinearity in the model, we use the variance inflation factor (VIF) test and the results are presented in Table 4. As a decision rule, a value of VIF beyond 10 indicates severe multicollinearity, thereby needing adjustments in the model for the results to be valid. Table 4 shows low multicollinearity among the model's variables, with VIF values well below the threshold of 5, indicating a sufficient level of independence of the variables. The average VIF of 1.27 suggests that there is no collinearity between the variables, ensuring that each variable's unique contribution is clear.

Table 4: Variance Inflation Factor Test

Variables	VIF	1/VIF
GF	1.03	0.9691
REC	1.13	0.8811
GDP	3.22	0.3110
R&D	3.28	0.3046
URB	1.26	0.7918
FDI	1.01	0.9856
Mean VIF	1.82	

Source: authors' calculations

4.2 Baseline regression analysis

The results of a series of regression models aimed at estimating the effect of various independent variables on CO_2 emissions as well as renewable energy consumption are presented in Table 5. First, the coefficient of green finance (GF) is consistently negative across all five models. This indicates that there exists a negative and significant effect of GF on carbon emissions, or, in other words, increased green finance investment is associated with lower carbon emissions. Across the models, the magnitude of the negative relationship increases when more variables are added into the model. Second, the effect of GDP on CO_2 emissions is positive and significant with the increase in coefficient from 1.0415*** in Model 2 to 1.2845*** in Model 5, thereby suggesting that GDP is positively associated with carbon emissions. Third, the effects of R&D investments on carbon emissions are negative, while the magnitude decreases as we move along the models; still, the relationship remains significant throughout the estimations. A negative and significant coefficient indicates that when investment in R&D is increased, it leads to lower carbon emissions in the economy. Fourth, the urbanization variable is added in Models 4 and 5 and its coefficient is −0.0219** and −0.0184* respectively. This suggests that there exists a negative but significant association between urbanization and carbon emissions. Fifth, the effects of FDI (included in Model 5) are small but significant and the coefficient has a positive sign, depicting a positive association between FDI and CO_2 emissions. Finally, in Model 6 the coefficient of GF is 0.7417***, thereby suggesting that when GF increases by 1 unit, there is a subsequent rise in renewable energy consumption by 0.7417 units, ceteris paribus. This suggests that there is a strong positive association between green finance and renewable energy consumption, and it is statistically significant.

The comparison of the goodness of fit across models (R-square) indicates that the R^2 increases as we move from Model 2 to Model 5 from 0.357 to 0.745 and it is even higher for Model 6 – 0.659, thereby suggesting that Models 5 and 6 offer a good fit to the data. The conclusion that can be inferred is that green finance affects carbon emissions negatively, but its effect on renewable energy consumption is positive and significant. The environmental costs of higher growth are depicted by the positive association between GDP and CO_2. Furthermore, both R&D investments and urbanization show potential for reducing emissions since their effect is negative and significant, but FDI affects carbon emissions positively and weakly, thereby requiring careful policy considerations.

These results highlight the nature of the relationships among the variables and their collective impact on carbon emissions and REC, demonstrating the usefulness of stepwise regression in discerning the contribution of individual predictors in a complex multivariate context.

Table 5: Baseline Regression Results

	(1)	(2)	(3)	(4)	(5)	(6)	(8)
Variables	CO_2	CO_2	CO_2	CO_2	CO_2	*REC*	CO_2
REC							−0.0260** (0.0110)
GF	−0.0345** (0.0139)	−0.0604*** (0.0077)	−0.0510*** (0.0072)	−0.0464*** (0.0058)	−0.0465*** (0.0060)	0.7417*** (0.1722)	−0.0272*** (0.0067)
GDP		1.0415*** (0.0934)	1.0598*** (0.0595)	1.3193*** (0.1208)	1.2845*** (0.1159)	−20.3569*** (4.3519)	0.7558*** (0.2157)
R&D			−0.2174*** (0.0553)	−0.1865*** (0.0521)	−0.1921*** (0.0563)	3.0286 (2.3987)	−0.1135** (0.0363)
URB				−0.0217** (0.0095)	−0.0184* (0.0090)	0.8522*** (0.2673)	0.0037 (0.0100)
FDI					0.0010** (0.0003)	−0.0188* (0.0093)	0.0005 (0.0004)
Constant	2.1962*** (0.0834)	−8.5593*** (0.9398)	−8.3034*** (0.5656)	−9.3817*** (0.9428)	−9.2699*** (0.8406)	150.4749*** (30.5436)	−5.3622*** (1.6061)
R-squared	0.357	0.647	0.717	0.734	0.745	0.659	0.855

Notes: robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1
Source: authors' calculations

4.3 Robustness tests

Our study enhances the understanding of the determinants of carbon emissions and REC through a stepwise regression static panel model. To ensure consistency of the findings and their generalizability, the robustness check is done by employing the random effect model that helps in accounting for unobserved heterogeneity across both countries and periods. Additionally, we use the GMM model, which helps in addressing the endogeneity issues and thereby provides more reliable estimations. It also aids in exploring the lagged effects of carbon emissions. As shown in Model 2, the results indicate that carbon emissions have a significantly positive lagged effect.

Table 6: Robustness Analysis Results

	(1)	(2)	(3)
Variables	***RE***	***FE***	***GMM***
L.CO₂		0.6216***	0.8858***
		(0.1021)	(0.1261)
GF	−0.0448***	−0.0216***	−0.0093*
	(0.0055)	(0.0055)	(0.0051)
GDP	1.2172***	0.9307***	0.8585***
	(0.1676)	(0.1091)	(0.1147)
R&D	−0.1864***	−0.1689***	−0.1913***
	(0.0528)	(0.0377)	(0.0490)
URB	−0.0190*	−0.0145**	−0.0163***
	(0.0100)	(0.0059)	(0.0040)
FDI	0.0010	0.0011***	0.0012***
	(0.0006)	(0.0001)	(0.0003)
Constant	−8.5522***	−7.3432***	−6.9965***
	(1.3138)	(0.6131)	(0.8446)
***R*-squared**	0.744	0.882	-

Source: authors' calculations

In the robustness analysis, green finance (GF) maintains a negative coefficient across all models, reflecting its consistent mitigating effect on carbon emissions. GDP shows a positive coefficient, underscoring its role in increasing emissions. Research and Development presents a negative coefficient in all models, indicating its effectiveness in reducing emissions. Urbanization is negatively associated with carbon emissions in all models but with varying significance, suggesting a nuanced impact. Foreign Direct Investment (FDI) has a positive effect in FE and GMM models, revealing its complex relationship with emissions. Furthermore, both Models 2 and 3 of the robustness analysis shown in Table 6 indicate a positive coefficient of the lagged value of CO_2, which is significant at a 1% level. This suggests that the CO_2 emissions have a significant positive lagged effect over time, such that if carbon emissions are greater today then they will continue to rise in the subsequent periods as well.

The key findings from the stepwise regression shown in Table 5 are confirmed using the robustness analysis depicted in Table 6. This means that the regression results are reliable and valid, and it can be concluded that green finance is important for reducing carbon emissions and promoting renewable energy consumption at a global scale.

5. Discussion

The results show that there is a significant negative relationship between GF and CO_2, which implies that the higher the degree of green finance, the more effective it is in reducing the level of CO_2 emissions, emphasizing the direct role of green finance in reducing CO_2. In addition, based on the mediation model with REC as a mediating variable, the empirical result demonstrates the indirect role of GF in reducing CO_2 through REC, which emphasizes the importance of REC. Based on the level of control variables, some macroeconomic indicators have significant direct effects on CO_2. Specifically, R&D investment and urbanization are influential factors in reducing carbon emissions. This may be because investment in R&D implies that technological advances in green technologies such as carbon capture, sequestration and carbon utilization will effectively reduce CO_2. The role of urbanization in reducing emissions underscores the need for comprehensive urban planning and sustainable urban development technologies. Two significant factors that are expected to raise CO_2 emissions are economic development and FDI. This means that higher economic growth induces a significant rise in carbon emission, which indicates that there exists a positive connection between economic growth and CO_2 across various economies.

Anser (2019) and Hanif (2018) highlighted a positive association between FDI, GDP, and carbon emissions. Our study depicts similar findings as Dong et al. (2018), wherein the main problem is renewable energy and its contribution to decreasing CO_2 emissions. This means that clean energy acts as an effective substitute for fossil fuels, a crucial component in increased CO_2, contributing to the achievement of environmentally sustainable development. Furthermore, REC acts as an intermediate variable for analyzing the association between GF and CO_2 emissions and has contributed to previous studies. The results show that GF has a considerable mitigation impact on CO_2 emissions and inverse association between REC and carbon emissions. Glomsrd and Wei (2018) and Gianfrate and Peri (2019) have achieved similar results, discovering that GF promotes environmental sustainability by lowering carbon emissions. These empirical findings provide insights into the association between macroeconomic indicators and carbon emissions in various nations. Overall, this study deepens our understanding of the complex interactions between GF, environmental sustainability, and macroeconomic indicators across

nations. It investigates the potential of GF and REC for reduction of CO_2 emissions, while also depicting the indirect effect of economic indicators such as FDI and GDP on the environment. The research also determines green finance value as an environmental protection strategy and the indirect emission reduction impacts generated from intermediate variables.

This study highlights the importance of considering regional differences while evaluating the relationship between green finance and CO_2 emissions reduction. This has several policy implications, because it enables the policymakers to make region-specific strategies for achieving high-quality economic development and reduction of carbon emissions. Furthermore, the study's findings have implications for both international organizations as well as governments. This is so because the development of green finance projects like green bond issuance is necessary for attaining sustainable economic development and lower carbon emissions. The governments can stimulate renewable energy consumption using tax incentives and subsidies to meet their sustainable development goals. At the same time, international organizations can promote global cooperation by enabling the exchange of knowledge, and using such coordinated efforts, we can achieve global sustainable development by investing in green finance initiatives. The findings also indicate that renewable energy consumption is important for reducing carbon emissions and this means that governments can expand the capacity of such resources to reduce carbon emissions and thereby achieve a high-quality economic development. The findings of this study suggesting that R&D plays a significant role in reducing CO_2 emissions are confirmed in the existing studies and have several policy implications. More investment in R&D and fostering innovation lead to the adoption of cleaner as well as more efficient technologies, and based on that, it can be inferred that R&D accelerates the transition from a low carbon economy and thereby helps in tackling climate change issues.

6. Conclusion and Recommendations

This paper adds green finance as a central variable to the STIRPAT model. In the context of the big issuers of green bonds, the main aim is to study the direct impact of green finance on high-quality economic development, as well as the indirect impact through REC. REC was introduced as an intermediate variable to explore the transmission mechanism of green finance on carbon emissions. To achieve the stated research objectives, the mediation model is used to analyse the relationship among explanatory variables, control variables and mediating variables. This study highlights a critical and urgent issue: countries' relentless pursuit of economic growth often leads governments to underestimate and ignore environmental consequences. Economic prosperity remains the primary goal of nations, but the accompanying environmental challenges

and misfortunes are often overlooked. The findings highlight the urgent need for countries to develop and implement stringent environmental regulations while pursuing economic growth strategies. The coexistence of economic development and environmental sustainability is an imperative that cannot be ignored.

Energy consumption plays a crucial role in economic growth, and the research findings provide compelling evidence of the positive contribution of renewable energy to environmental well-being. Therefore, it can be said that constructing more renewable energy facilities can bring dual benefits of promoting economic growth and reducing environmental impact.

The results of the study indicate that the potential advantages of developing renewable energy infrastructure are the pathway for achieving economic and environmental objectives. The main findings depict the association between green finance and carbon emissions. The results represent the need for strict regulatory measures and policy actions to mitigate the adverse environmental effects of economic development. In addition, our analysis also explores how governments formulate strategies to mitigate the adverse impact of foreign direct investment on the environment, like promoting labour-intensive production methods rather than capital-intensive ones, and encouraging businesses to adopt environmentally friendly practices and technologies. Furthermore, the study also emphasizes the potential of green finance, an area that has yet to be extensively researched. It also provides the evidence of green finance's effectiveness in reducing carbon emissions and promoting high-quality economic development. It encourages governments and regulatory bodies to promote green finance with the help of fiscal policies and to prioritize green initiatives. Active promotion of green finance products, incorporation of environmental and biodiversity funds, weather derivatives, nature-linked securities, green investment funds, green bonds, and renewable energy investments are also recommended to foster sustainable economic growth.

To sum up, our findings have crucial implications for both theory and policy. Integration of green finance as a core element into the STIRPAT model opens up new avenues for research in this field. In addition, future research can be based on this framework and potentially focus on different regions and nations using advanced econometric models. Researchers can further investigate the channels through which economic growth factors influence the environment, exploring scale effects, aggregate effects, and technological effects separately. Therefore, it can be stated that this study emphasizes the urgent need to balance economic prosperity with environmental protection and provides valuable guidance for policymakers and stakeholders to address the complex challenges of accomplishing high-quality economic development.

References

Appiah-Konadu, P. A. U. L. (2013). The Effect of Trade Liberalization on the Environment: A Case Study of Ghana. [Doctoral dissertation]. University of Ghana.

Allevi, E., Basso, A., Bonenti, F., Oggioni, G., Riccardi, R. (2019). Measuring the Environmental Performance of Green SRI Funds: A DEA Approach. *Energy Economics,* 79, 32–44. https://doi.org/10.1016/j.eneco.2018.07. 023

Anser, M. K. (2019). Impact of Energy Consumption and Human Activities on Carbon Emissions in Pakistan: Application of STIRPAT Model. *Environmental Science and Pollution Research,* 26(13), 13453–13463. https://doi.org/10.1007/s11356-019-04859-y

Atici, C. (2012). Carbon Emissions, Trade Liberalization, and the Japan–ASEAN Interaction: A Group-wise Examination. *Journal of the Japanese and International Economies*, 26(1), 167–178. https://doi.org/10.1016/j. jjie.2011.07.006

Bughio, A., Teng, Y., Tunio, R.A., Das, G., Jamali, R., Shar, R.U. (2023). The Short- and Long-run Causal Correlation between Green Finance, Renewable Energy Consumption, and Economic Growth. *Energy & Environment*. https://doi.org/10.1177/0958305X231187036

Chikaraishi, M., Fujiwara, A., Kaneko, S., Poumanyvong, P., Komatsu, S., Kalugin, A. (2015). The Moderating Effects of Urbanization on Carbon Dioxide Emissions: A Latent Class Modelling Approach. *Technological Forecasting and Social Change*, 90, 302–317. https://doi.org/10.1016/j.techfore.2013.12.025

Cheng, Z., Kai, Z., Zhu, S.W.J. (2023). Does Green Finance Regulation Improve Renewable Energy Utilization? Evidence from Energy Consumption Efficiency. *Renewable Energy*, 208, 63–75. https://doi.org/10.1016/j.renene.2023.03.083

Dietz, T., Rosa, E. A. (1997). Effects of Population and Affluence on Carbon Emissions. *Proceedings of the National Academy of Sciences*, 94(1), 175–179. https://doi.org/10.1073/pnas.94.1.175

Dincer, I. (2000). Renewable Energy and Sustainable Development: A Crucial Review. *Renewable and Sustainable Energy Reviews*, 4(2), 157–175. https://doi.org/ 10.1016/S1364-0321(99)00011-8

Dong, K., Sun, R., Jiang, H., Zeng, X. (2018). Carbon Emissions, Economic Growth, and the Environmental Kuznets Curve in China: What Roles Can Nuclear Energy and Renewable Energy Play? *Journal of Cleaner Production*, 196, 51–63. https://doi.org/10.1016/j.jclepro.2018.05.271

Du, J.T., Shen, Z.Y., Song, M.L., Vardanyan, M. (2023). The Role of Green Financing in Facilitating Renewable Energy Transition in China: Perspectives from Energy Governance, Environmental Regulation, and Market Reforms. *Energy Economics*, 120. https://doi.org/10.1080/17583004.2023.2251934

Gill, A. R., Viswanathan, K. K., Hassan, S. (2018). A Test of Environmental Kuznets Curve (EKC) for Carbon Emission and Potential of Renewable Energy to Reduce Greenhouse Gases (GHG) in Malaysia. *Environment, Development and Sustainability*, 20(3), 1103–1114. https://doi.org/10.1007/s10668-017-9929-5

Gianfrate, G., Peri, M. (2019). The Green Advantage: Exploring the Convenience of Issuing Green Bonds. *Journal of Cleaner Production*, 219, 127–135. https://doi.org/10.1016/j.jclepro.2019.02.022

Glomsrød, S., Wei, T. (2018). Business as Unusual: The Implications of Fossil Divestment and Green Bonds for Financial Flows, Economic Growth and Energy Market. *Energy for Sustainable Development,* 44, 1–10. https://doi.org/10.1016/j.esd.2018.02.005

Grossman, G. M., Krueger, A. B. (1995). Economic Growth and the Environment. *The Quarterly Journal of Economics,* 110(2), 353–377. https://doi.org/10. 2307/2118443

Hamid, I., Alam, M. S., Murshed, M., Jena, P. K., Sha, N., Alam, M. N. (2022). The Roles of Foreign Direct Investments, Economic Growth, and Capital Investments in Decarbonizing the Economy of Oman. *Environmental Science and Pollution Research International,* 29(15), 22122–22138. https://doi.org/10.1007/ s11356-021-17246-3

Hanif, I. (2018). Impact of Economic Growth, Non-renewable and Renewable Energy Consumption, and Urbanization on Carbon Emissions in Sub-Saharan Africa. *Environmental Science and Pollution Research*, 25(15), 15057–15067. https://doi. org/10.1007/s11356-018-1753-4

Höhne, K., Fekete, G. (2012). Mapping of Green Finance Delivered by IDFC Members in 2011. Ecofys.

Hou, H., Wang, Y.Y., Zhang, M.L. (2023). Green Finance Drives Renewable Energy Development: Empirical Evidence from 53 Countries Worldwide. *Environmental Science and Pollution Research International*, 30(33). https://doi.org/10.1007/s11356-023-28111-w

Jiang, L., Zhou, H. F., Bai, L., Zhou, P., Gill, A. R., Viswanathan, K. K., Hassan, S. (2018). Does Foreign Direct Investment Drive Environmental Degradation in China? An Empirical Study Based on Air Quality Index from a Spatial Perspective. *Journal of Cleaner Production*, 176, 864–872. https://doi.org/10.1016/j. jclepro.2017.12.048

Khan, A. Q., Saleem, N., Fatima, S. T. (2018). Financial Development, Income Inequality, and Carbon Emissions in Asian Countries using the STIRPAT Model. *Environmental Science and Pollution Research,* 25(7), 6308–6319. https://doi.org/10.1007/s11356-017-0719-2

Khan, S., Akbar, A., Nasim, I., Hedvicáková, M., Bashir, F. (2022). Green Finance Development and Environmental Sustainability: A Panel Data Analysis. *Frontiers in Environmental Science,* 10. https://doi.org/10.3389/fenvs.2022.1039705

Lin, W., Chen, B., Luo, S., Liang, L. (2014). Factor Analysis of Residential Energy Consumption at the Provincial Level in China. *Sustainability*, 6(11), 7710–7724. https://doi.org/10.3390/su6117710

Liu, L., Li, X. (2024). A Study on the Impact of Green Finance on the High-Quality Economic Development of Beijing–Tianjin–Hebei Region. *Sustainability*, 16(6), 2433. https://doi.org/10.3390/su16062433

Merican, Y., Yusop, Z., Noor, Z. M., Hook, L. S. (2007). Foreign Direct Investment and Pollution in Five ASEAN Nations. *International Journal of Economics and Management*, 1(2), 245–261.

Mujtaba, A., Jena, P. K., Joshi, D. P. P. (2021). Growth and Determinants of Carbon Emissions: Evidence from Selected Asian Emerging Economies. *Environmental Science and Pollution Research,* 28(29), 39357–39369. https://doi.org/10.1007/s11356-021-13078-3

Mujtaba, A., Jena, P. K., Bekun, F. V., Sahu, P. K. (2022). Symmetric and Asymmetric Impact of Economic Growth, Capital Formation, Renewable and Non-renewable Energy Consumption on the Environment in OECD Countries. *Renewable and Sustainable Energy Reviews,* 160, 112300. https://doi.org/10.1016/j.rser.2022. 112300

Mumuni, S., Lefe, Y.D.H. (2023). Greening the Environment: Do Climate-related Development Finances and Renewable Energy Consumption Matter? An African Tale. *Carbon Management,* 14(1). https://doi.org/10.1080/17583004.2023.2251934

Nawaz, M. A., Seshadri, U., Kumar, P., Aqdas, R., Patwary, A. K., Riaz, M. (2021). Nexus between Green Finance and Climate Change Mitigation in N-11 and BRICS Countries: Empirical Estimation through Difference in Differences (DID) Approach. *Environmental Science and Pollution Research*, 28, 6504–6519.

Ning, W., She, J. H. (2014). An Empirical Study on the Dynamic Relationship between Green Finance and Macroeconomic Growth. *Seeker,* 8, 62–66.

Onder, H. (2012). Trade and Climate Change: An Analytical Review of Key Issues. *World Bank Economic Premise*, 56, 1–8.

Petrović, R. M., Kocić, N., Stojanović, R. B. (2020). The Importance of Renewable Energy Sources for Sustainable Development. *Economics of Sustainable Development,* 4(2), 15–24. https://doi.org/10.5937/ESD2002016P

Phillips, P. C., Hansen, B. E. (1990). Statistical Inference in Instrumental Variables Regression with I(1) Processes. *The Review of Economic Studies,* 57(1), 99–125. https://doi.org/10.2307/2297545

Poberezhna, A. (2018). We Are Addressing Water Sustainability with Blockchain Technology and Green Finance. In Transforming Climate Finance and Green Investment with Blockchains (pp. 189–196). *Academic Press*. https://doi.org/10.1016/B978-0-12-814447-3.00014-8

Salazar, J. (1998). Environmental Finance: Linking Two Worlds. In a Workshop on Financial Innovations for Biodiversity, Bratislava (pp. 2-18).

Stretesky, P. B., Lynch, M. J. (2009). A Cross-national Study of the Association between per capita Carbon Dioxide Emissions and Exports to the United States. *Social Science Research,* 38(1), 239–250. https://doi.org/10.1016/ j.ssresearch.2008.08.004

Su, R. G., Zhao, X. L., Chen, H. (2019). Analysis of the Mechanism and Path of Green Finance in Supporting the Development of Green Industries. *Finance Accounting Monthly,* 40(11), 153–158. https://doi.org/10.21834/jabs.v8i25.427

Xing, Y., Kolstad, C. D. (2002). Do Lax Environmental Regulations Attract Foreign Investment? *Environmental and Resource Economics*, 21(1), 1–22. https://doi.org/10.1023/A:1014537013353

Yang, Z. (2023). The Impact of Green Finance on High-quality Economic Development in China: Vertical Fiscal Imbalance as the Moderating Effect. *Sustainability,* 15(12), 9350. https://doi.org/10.3390/su15129350