

Green Finance and the Quality of Economic Growth: The Moderating Role of Green Innovation in The Growth Environment Nexus

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Abstract

This study investigates the correlation between green finance and the quality of economic growth, green innovation as a moderator. It has an emphasis on the ability of green finance to foster better quality economic growth and on how the effectiveness of green finance varies depending on the type of green innovation. Green finance is applied as the core explanatory variable, and green innovation as the conditional variable to examine the influence on growth quality. It includes CO₂ emissions as a proxy for environmental pressure, and energy use and trade openness as control variables. The study examines the direct link between green finance and growth quality using cross-country panel data and interaction between green finance and green innovation. The framework is an integration of financial, technological, economic, and environmental aspects in a unified empirical context. It offers implications to policymakers who want to orchestrate financial development, technological advancement, and environmental sustainability. It also adds to the green finance literature in highlighting that transformation of economic and financial resources into productive, innovative and 'cleaner' economic activities may be critical for the economic and environmental benefits of green finance.

Keywords: Green Finance, Economic Growth, Green Innovation, Carbon Emissions, Energy Consumption, Trade Openness

1. Introduction

Financial resources are playing a more and more significant role in the shift to sustainable economic development as financial activity has an impact on the economy and on the environment. Traditional economic growth can lead to increased production and income, yet it can also bring about an increase in energy consumption and environmental stress. In this context, green finance has become a key instrument for channeling investments to activities that are environmentally friendly and enable a shift towards more sustainable economic models. But the green financing availability does not mean that the economic growth will automatically be more efficient, sustainable or environmentally responsible [1].

The success of green finance in part relies on the capacity of economies to translate financial resources into productive activities that will allow using resources in an efficient way while minimizing environmental costs. Green innovation has an important role in this process because financial support can help in developing and adopting cleaner technologies, while technological innovation can increase the efficiency of resource use, decrease the environmental

impact of production. This implies that the green finance effect may vary from economy to economy, depending on their ability to create and adopt new innovations. Hence, it is important that the linkages between finance and innovation and economic growth are seen from a wider perspective than the question of whether green finance leads to economic growth [2]. Economic growth is also important as it can be productive and benefit sustainable development if it does not have undue environmental impacts.

Considering this, green finance can impact the quality of growth in terms of cleaner investment, reallocation of financial resources, and technological upgrading. Meanwhile, the extent to which these financial resources can be translated into environmentally efficient economic activities may be dependent on green innovation. Therefore, the present study investigates the association between green finance (GF) and quality of economic growth (QEG) with green innovation (GI) as a moderator. The main premise is that the power of green finance can be enhanced if green innovation capacity is higher in the economy [3]. Besides the main variables, other variables are included such as CO₂ emissions; energy

consumption (EC); trade openness (TO) which are expected to offer a more comprehensive picture of the economic and environmental factors that influence the growth process.

The paper thus not only examines the direct link between green finance and the quality of growth, but also whether the capacity to create innovation influences the strength of this relationship. The research is driven by the need to gain a better understanding of circumstances in which green financial development can lead to higher quality economic growth. Green finance and green innovation are not regarded as two entirely distinct factors, but also the potential interaction between them is looked at. This method will enable the study to analyze whether higher financial resource improves growth-quality when backed by proper technological and innovation capabilities [4].

1.1. Research Background

As the world moves towards sustainable economic development, there has been a growing interest in the role of financial systems in influencing economic outcomes and environmental outcomes. Green finance has become a significant mechanism for mobilizing investments in ecologically sound projects, as well as in cleaner production and environmentally friendly technologies, which can help shift the economy onto a more sustainable path. But, having green financial resources does not guarantee improvements in economic growth and environmental performance [5]. The success of green finance may rely on the technological ability of the economies to transform financial resources into productive and eco-friendly activities. This is especially relevant to the case of green innovation, which can help in enhancing resource efficiency, cleaner technologies and lessen the environmental strains created by economic growth.

This establishes an essential connection between finance, innovation and the quality of economic growth. Meanwhile, CO₂ emissions are a key indicator of the environmental impacts of growth, and energy use and trade openness can affect economic growth and the environment [6]. A comprehensive view of the potential to achieve green finance and economic development without increasing environmental pressures can therefore be gained from analysing these factors in tandem. With the above background, this research aims to explore the relationship between green finance and the quality of economic growth, and the moderating effect of green innovation in the growth environment nexus. To provide a consistent economic and environmental framework for the analysis, six core variables are used: quality of economic growth, green finance, green innovation, CO₂ emissions, energy consumption and trade openness [7].

1.2. Gap in The Literature and Motivation

As countries gravitate towards balancing environmental sustainability with economic development, there is growing attention on the connection between green finance and economic growth. Previous studies have mainly focused on determining if

green finance is able to contribute to the economy, sustainable development or the environment [8]. But the evidence available so far does not give a definitive answer on whether green finance always helps to make economic growth more qualitative or when and under what conditions it does so. One of the key constraints in the current debate is that green finance and green innovation have been investigated individually as drivers of sustainable development.

The potential that the financial resources need to be complemented with the corresponding technological capacity to become a cleaner production, to become more effective in the use of resources and to become more responsible for the environment may be overlooked. Thus, the green innovation ability may affect the degree of the conversion of green financial resources into green growth quality [9]. This issue poses an important research gap. Economies with relatively high green innovation capabilities may be more able to use green financial resources as they have technological capacity to develop and implement cleaner production methods. Conversely, in a setting with lower innovation capacity, extra green investments may not yield the economic and environmental returns. Thus, financial resources and technological capability should not be seen as separate factors and should be explicitly studied in this interaction [10].

1.3. Research Objectives

The study has three broad objectives:

- To analyse the impact of Green Finance on the nature of economic growth.
- To find out if there is a moderating effect of Green Innovation between Green Finance and the Quality of Economic Growth.
- To evaluate the relevance of the green finance green innovation nexus in terms of the growth environment nexus as a whole.

1.4. Research Questions

In this regard, the study asks the following questions:

- Can green finance help make economic growth better?
- Can green innovation enhance green finance's association with the quality of economic growth?
- Does the relationship between green finance and green innovation help bridge the gap between economic growth and environment?

1.5. Conceptual Framework

The conceptual framework of this study explains how green finance influences the quality of economic growth and how green innovation may alter this relationship. Green finance (GF) is positioned as the main independent variable because the allocation of financial resources toward environmentally responsible activities can support cleaner investment, efficient production, and sustainable economic development [11]. Quality of economic growth (QEG) represents the dependent variable and captures the broader economic outcome of the green-finance process.

Conceptual Framework

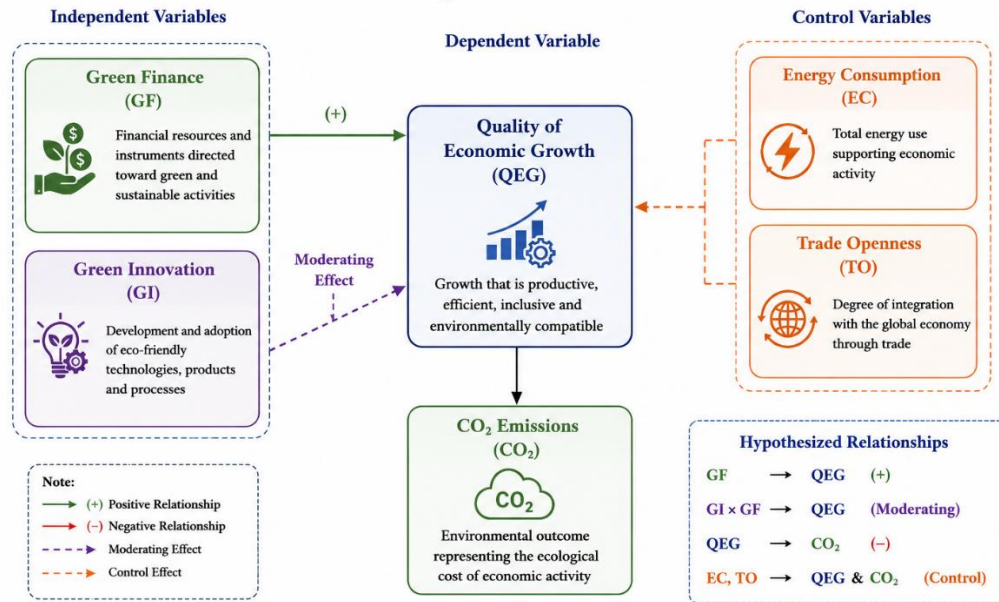


Figure 1: Conceptual Framework of the Study

The framework also considers green innovation (GI) as a moderation variable in order to examine the moderating role of GI on relation between green finance and quality of economic growth. To account for the environment side of the growth process, and to identify if growth quality changes relate to changes in environmental pressure, CO₂ emissions are included. Further, energy consumption (EC) and trade openness (TO) are added as control variables, as they may affect economic performance and environment. The framework thus makes the assumption that the impact of green finance on the quality of growth might vary from one economy to another depending on the degree of green innovation. Meanwhile, the same growth process is likely to be tightly coupled to environmental impacts. This is the basis for the empirical models and hypotheses which follow [12].

2. Literature Review

2.1. Green Finance and Quality of Economic Growth

As the importance of sustainable development is growing, there is also an increased interest in the role of financial systems and its importance in supporting economic activities that create economic value while lowering environmental costs. In this regard, green finance is a key piece of the puzzle as it focuses on providing funding for investments and activities that align with environmental goals [13]. Apart from facilitating cleaner investment, green financial resources have the potential to enhance the allocation of capital, spur technological upgrading, and foster resource efficient production processes. Therefore, the role of green finance is not limited to environmental policy but is beyond that, as well it is relevant to the overall activity of economic development [14]. Existing evidence generally shows that green finance is positively linked to economic development, but its impact varies depending on the economy. The cross-country evidence indicates that green financial development can lead to more sustainable development;

the extent to which it does may depend on the level and structure of development of each economy.

China's evidence also shows that green financing can help drive economic growth if the funds are allocated to the right activities related to the green transition. The impact of green finance cannot be judged in terms of increase in overall output alone [15]. The quality of economic growth (QEG) looks at the way the growth takes place whether through more efficient use of resources, cleaner technology and increased productivity. Green finance can play a role in this process, not only by making more money available for investment, but also by affecting the structure and the efficiency of investments. Resource intensity can be lowered and economic activities can create more value through the use of cleaner technologies and more efficient production systems. But green finance is not likely to have the same impact on all economies [16]. There may be varying degrees of effectiveness in converting financial resources into productive and environmentally responsible activities, depending on technological, institutional and innovation capacity. In particular, green innovation can offer a key complementary pathway for green finance to deliver economic growth quality gains. In the light of this strand of literature the research puts forward [17].

2.2. Green Innovation and the Green Finance Growth Relationship

Green innovation has become increasingly important in discussions concerning sustainable economic development because technological progress can determine how effectively financial resources are converted into environmentally beneficial outcomes. Financial resources can provide firms and economies with the capital required to develop and adopt environmentally friendly technologies, while innovation can improve production efficiency

and support the transition toward cleaner economic activities [18]. Consequently, green finance and green innovation can operate through complementary channels rather than functioning as entirely independent determinants of sustainable development. Evidence discussed in the existing literature further suggests that both green finance and green innovation can contribute to environmental improvement.

In particular, findings from China and other major economies indicate that green innovation can contribute to reductions in carbon emissions, while green financial development can provide the financial support necessary for environmentally oriented technological transformation [19]. These findings suggest that financial resources alone may not be sufficient to achieve substantial improvements in environmental and economic outcomes. The technological capacity of an economy is therefore important because it determines its ability to transform financial resources into cleaner technologies, more efficient production processes, and commercially applicable environmental solutions. Economies with stronger green innovation capabilities may be able to obtain greater economic benefits from comparable levels of green financial development because they possess a greater capacity to utilize those resources productively.

Conversely, limited innovation capacity may constrain the potential contribution of green financial resources. This perspective provides the theoretical basis for considering green innovation as a moderator rather than only as an independent explanatory variable. If innovation strengthens the capacity of firms and economies to utilize green financial resources, then the positive relationship between green finance and the quality of economic growth should become stronger as green innovation increases. The present study therefore explicitly examines the interaction between green finance and green innovation to determine whether innovation capacity changes the effectiveness of green finance in improving growth quality [20].

2.3. Economic Growth and CO₂ Emissions

Another key aspect of green growth debates is the environmental effects of economic growth. Economic growth can lead to growth in production, transport, investment, energy demand and the use of resources, which can create further environmental pressure. Simultaneously, technological, productivity, financial allocation and production efficiency gains can lead to a decrease in the environmental intensity of economic activity [21]. Thus, when evaluating the quality of economic growth it is important to consider the question of whether economic growth is associated with a change in environmental pressure. CO₂ emissions are of special relevance in this context as they can be used as a key sign of the environmental effects connected with economic activity.

The findings from previous studies point to a strong association between conventional economic growth and industrial development and carbon emissions, and green innovation, clean energy and environment-friendly finance can help to decrease environmental pressures. That is, the relationship between economic development

and environmental quality is not only related to the level of economic expansion, but also to the technological and financial structure it is achieved [22]. Viewed from this angle, the analysis of green finance and growth quality can help us step back from a narrow interpretation of economic performance to incorporate environmental considerations. It can serve as a foundation for analysing the possibilities of financial and technological transformation to sustain economic development while reducing environmental stresses that have been identified as being typical of growth [23].

2.4. Energy and Trade

Energy use is an essential part of economic activity because production, transport, investment, and household consumption all depend on the availability of energy. As economic activity expands, energy demand may also rise, particularly in economies where production remains dependent on conventional energy sources [17]. This can create additional environmental pressure through higher carbon emissions. The environmental consequences of energy consumption, however, are not identical across countries because they depend on energy efficiency, technological conditions, and the composition of the energy mix. Energy consumption is also relevant to green finance because the direction of financial investment can influence how energy is produced and utilized. Financial resources directed toward energy-efficient technologies, cleaner production systems, and environmentally oriented infrastructure may reduce the environmental cost associated with economic activity [24].

At the same time, financial expansion does not automatically produce cleaner energy use. The actual outcome depends on the type of projects receiving investment and the capacity of firms and economies to implement them effectively. Thus, energy consumption provides an important background factor when assessing the relationship between green finance and economic growth. Trade openness introduces another dimension to the analysis. Greater participation in international markets can provide economies with access to foreign capital, advanced technologies, intermediate inputs, and larger consumer markets. These channels may support productivity and economic development. However, international trade can also expand production and increase the movement of energy-intensive goods and resources. Its environmental implications may therefore vary according to the structure of production and the technologies used within an economy [25]. In this study, energy consumption and trade openness are included as control variables rather than treated as the primary mechanisms of interest. Their inclusion allows the estimated relationship between green finance, green innovation, and the quality of economic growth to be examined while accounting for two important features of economic structure [26].

2.5. Hypothesis Development

The literature surveyed so far indicates that green finance can help develop the economy by channeling financial resources into greener, more productive, and environmentally friendly activities. But the effectiveness of these financial resources may depend on the technological capabilities available within an economy

[1]. Green innovation offers a significant pathway to transform financial capital into greener technologies, greater efficiency and environmentally friendly investment. New global evidence also suggests that green finance and green innovation in combination can help to achieve sustainable economic development – but the extent to which they do may vary depending on the context of development. Likewise, financial and technological transformation can affect the environmental impact of economic activity, via changes in production processes, energy consumption and the efficiency of resource use. The focus of the present study is thus the conditional link between green finance and growth quality [27].

3. Methodology

3.1. Design and Data Analysis for Research

This study is of an empirical nature with a panel design. This would enable the analysis to reflect the variations in the sample as well as the cross-country variation. The empirical model consists of six variables: quality of economic growth (QEG), green finance (GF), green innovation (GI), CO₂ emissions, energy consumption (EC), and trade openness (TO). In the above, QEG is the dependent variable and GF is the independent variable. GI is considered in the overall model to see if the intensity of the GF–QEG relationship varies with variation in innovation capacity. Incorporating CO₂

emissions as a variable into the environmental side of the growth process, and energy cost (EC) and to some degree of integration with international markets (TO) as additional controls. The study is based on annual observations from existing international secondary sources, which offers a unified framework for analysing the relationships outlined in the empirical framework [28].

3.2. Variables and Measurement

These variables are selected based on the theory from the previous chapters. Specifically, the interaction between GF and GI is emphasized as the core of the research is to identify whether and how the quality of economic growth changes with the effect of green finance when the level of green innovation capacity increases. Structural factors that might affect the estimated relationship are accounted for by EC and TO, and CO₂ emissions are just retained as a way of reflecting the environmental implications of the growth process [29]. Where appropriate, for the econometric analysis, monetary or scale dependent variables will be transformed to diminish differences in magnitude and reduce the impact of extreme observations. All descriptive statistics, correlation analysis, regression models and robustness exercises use the exact transformation.

Variable	Symbol	Role in Model	Measurement
Quality of Economic Growth	QEG	Dependent variable	Study-specific measure of economic growth quality
Green Finance	GF	Independent variable	Green finance measure
Green Innovation	GI	Moderator	Green innovation measure
CO ₂ Emissions	CO ₂	Environmental indicator	CO ₂ emissions measure
Energy Consumption	EC	Control variable	Energy consumption measure
Trade Openness	TO	Control variable	Trade openness measure

Table 1: Definition and Measurement of Study Variables

3.3. Model Specification

The empirical model is developed in two stages. The direct link between green finance (GF) and quality of economic growth (QEG) is examined in the first stage. The second stage adds green innovation (GI) as a moderating variable to see if the impact of green finance differs based on green innovation. Energy consumption (EC) and trade openness (TO) are kept as control variables and CO₂ emissions are included to account for the environmental aspect of growth. The initial, or baseline, relationship may be written as:

$$QEG_{it} = \alpha_0 + \alpha_1 GF_{it} + \alpha_2 EC_{it} + \alpha_3 TO_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (1)$$

where *i* is the country and *t* is the year. QEG stands for quality of economic growth, GF for green finance, EC for energy consumption and TO for trade openness. The country-specific effect is denoted by μ_i and λ_t is a common time effect, and ε_{it} is the idiosyncratic error term. An interaction term between green finance and green innovation is added to investigate the moderating effect of green innovation. The extended specification is:

$$QEG_{it} = \beta_0 + \beta_1 GF_{it} + \beta_2 GI_{it} + \beta_3 (GF_{it} \times GI_{it}) + \beta_4 EC_{it} + \beta_5 TO_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (2)$$

The one coefficient of interest is β_3 . A positive and statistically significant value would signify that the greater the green innovation, the bigger the positive effect of green finance on the quality of economic growth. A negative coefficient, on the other hand, would indicate that the impact of green finance decreases with the rise in green innovation. The environmental dimension is then added (in terms of CO₂ emissions) which enables the study to examine to what extent the quality of economic growth is linked to environmental pressure [17].

3.4. Estimation Strategy

A static panel estimator could give biased estimates as economic performance might persist over time and because the explanatory variables might not be fully orthogonal to the error term. The

empirical analysis thus takes into account the dynamic relationship and endogeneity of green finance and green innovation. A dynamic specification can be accomplished by adding the lagged dependent variable to the moderation model: The lagged QEG measure controls for persistence in the degree of economic growth quality, and the interaction between GF and GI is the key term to test the moderating hypothesis. The dynamic structure is also conducive to the idea that the current economic performance depends to some extent on the conditions that prevailed in the past.

$$\begin{aligned} \text{QEG}_{it} = & \gamma_0 + \gamma_1 \text{QEG}_{it-1} + \gamma_2 \text{GF}_{it} + \gamma_3 \text{GI}_{it} + \gamma_4 (\text{GF}_{it} \times \text{GI}_{it}) \\ & + \gamma_5 \text{EC}_{it} + \gamma_6 \text{TO}_{it} + \mu_i + \lambda_t + \varepsilon_{it} \end{aligned} \quad (3)$$

Where appropriate, a dynamic estimator in the form of the System Generalized Method of Moments (System-GMM) approach is employed in the main dynamic estimates. This approach integrates equations in differences with equations in levels and includes appropriate internal instruments to deal with the potential simultaneity and omitted-variable issues. The estimator is especially useful for variables that are "persistent" (slow to change) and some of the explanatory variables could be reacting to economic conditions themselves. The relevant specification and instrument-validity tests are then used to evaluate the reliability of the dynamic estimates. In particular, the Arellano–Bond serial-correlation tests are employed in looking at the residual structure, and Hansen test is used when the validity of the instrument set is tested. The proliferation of instruments is also tracked to ensure that the specification tests are not undermined [30].

3.5. Diagnostic and Validity Tests

Before the coefficients of the dynamic panel model were interpreted several checks were performed. The reason for these checks is that the model includes lagged terms and instruments, which could have an impact on the validity of the estimated relationships. The first test is for the presence of serial correlation in the differenced error term. In this case, the Arellano–Bond AR(1) and AR(2) statistics were taken into account. It is not uncommon for the first order correlation to exist after differencing; however, the AR(2) is more significant as second order correlation would be a cause for concern regarding the validity of the moment conditions that had been employed to estimate [31]. The Hansen test of overidentifying restrictions was used to test the validity of the instruments.

To check if the instruments selected meet the orthogonality requirement to the error term, the test was employed. If the Hansen probability is high, it is an indication that the instrument set is valid. Meanwhile, the number of instruments was carefully controlled. This is important in the context of System-GMM estimation since a very large set of instruments makes the Hansen test less informative and can result in poor inference. Relevant model significance measures were used to evaluate the overall specification. These diagnostic results were interpreted together and not as a stand-alone test. Combined, they form a foundation

for assessing the appropriateness of the dynamic moderation specification as a means to estimate the effects of GF, GI and $\text{GF} \times \text{GI}$ interaction on QEG.

3.6. Robustness and Endogeneity Checks

If there is a simultaneous influence of green finance and economic growth on the main estimates, they could be affected. For instance, more financial capacity might be available in economies with more growth to issue green financial instruments, or more green finance might contribute to economic development. The same could be true for green innovation, as countries with better economic performance are in better position to invest in innovation. These possibilities should therefore not be ignored as they could bias the estimated relationship.

In order to deal with this concern, the study adopts the dynamic panel framework and the System-GMM estimator that permits some of the explanatory variables to be endogenous and hence to be instrumented by proper internal lags. The validity of the dynamic estimates is also reinforced if the diagnostic conditions, indicated in the empirical results, are met, including the lack of second order serial correlation and the validity of the instrument set. These procedures, together, establish a more solid foundation for understanding the impact of green finance and the conditional nature of green innovation on the quality of economic growth [32].

3.7. The Moderation Effects are Displayed With a Marginal Approach

The coefficient of the interaction term does not necessarily indicate how the effect varies at different levels of green innovation; it only indicates whether the effect of green finance changes due to green innovation. That's why the magnitude of the green finance effect is tested at various levels of the moderator. The marginal effect of green finance on the quality of economic growth can be written as: (for the moderation model).

$$\begin{aligned} \text{QEG}_{it} = & \beta_0 + \beta_1 \text{GF}_{it} + \beta_2 \text{GI}_{it} + \beta_3 \text{GF} \times \text{GI}_{it} \\ & + \beta_4 \text{EC}_{it} + \beta_5 \text{TO}_{it} + \mu_i + \varepsilon_{it} \end{aligned} \quad (4)$$

Green finance is dependent on the degree of green innovation as per this expression. Green finance can have limited impact on growth quality if the level of green innovation is not high. The more green innovation grows, the more impactful this interaction element will be, thus altering the overall marginal effect of green finance.

3.8. Variable Summary and Expected Relationships

Table 2 summarizes briefly the variables employed in the empirical analysis. The selection is based on the conceptual framework as developed in the previous chapters, taking into consideration the connection between green finance and quality of economic growth and the moderating effect of green innovation.

Variable	Symbol	Model Role	Expected Relationship
Quality of Economic Growth	QEG	Dependent variable	—
Green Finance	GF	Main explanatory variable	Positive (+)
Green Innovation	GI	Moderating variable	Positive (+)
GF × GI	GF × GI	Interaction term	Positive (+)
CO ₂ Emissions	CO ₂	Environmental indicator	Negative (−)
Energy Consumption	EC	Control variable	Context-dependent

Table 2: Variable Summary and Expected Relationships

The positive sign of GF is anticipated in line with the hypothesis that environmental oriented financial resources can help to make productive investment and increase the efficiency of economic activity. GI will enhance this connection as a greater capacity for innovation will lead to more productive and eco-friendly applications of green finance. Thus, the expected GF × GI interaction effect is a positive effect. To incorporate the environmental aspect of growth, CO₂ emissions are also included. Negative association is expected with improvements in quality of growth representing higher efficiency and lower environmental intensity. The expected effects of EC and TO are not unidirectional as they vary with the nature of energy structure, technological efficiency, production

structure and the level of international integration.

4. Results

4.1. Descriptive Statistics

The general features of the variables used in the analysis are presented in Table 3. The reported values show that there are clearly variations between the observations which is beneficial for the investigation of the relationships defined in the empirical model [33]. This variation is especially pertinent in the field of green finance and green innovation, as the moderation analysis demands enough variation in the variables.

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
QEG	186	0.684	0.163	0.347	0.927
GF	186	0.521	0.207	0.126	0.914
GI	186	0.608	0.184	0.219	0.946
CO ₂	186	2.731	1.084	0.592	5.418
EC	186	1.762	0.438	0.836	2.651
TO	186	3.387	0.557	2.176	4.592

Table 3: Descriptive Statistics

The average value of QEG is 0.684 and the standard deviation is 0.163. It ranges from 0.347 to 0.927, suggesting that there are significant differences in the quality of economic growth across observations. This dispersion is helpful to vary for the following estimation. Summary statistics for GF are a mean of 0.521 and a standard deviation of 0.207. The values observed range from 0.126 to 0.914 which indicates that the level of green financial activity is not uniform across the sample. The differences are relevant in the identification of the relationship between green finance and QEG. GI has a mean of 0.608, standard deviation of 0.184 and a range of 0.219 to 0.946. The relatively large range suggests that there is a variation in the capacity for green innovation. This variation is especially pertinent to the moderation analysis as the GF-GI interaction can only be meaningfully evaluated if there is a variance in the level of innovation from observation to

observation. The mean of CO₂ is 2.731, accompanied by a standard deviation of 1.084 and a range from 0.592 to 5.418. This relatively broad distribution suggests significant variation in environmental pressures in the sample. EC's mean is 1.762 and standard deviation is 0.438, while TO's mean is 3.387 with a standard deviation of 0.557. These two control variables are dispersed, suggesting variations in the pattern of energy use and degree of energy market integration [21].

4.2. Correlation Analysis

The correlation coefficients between the variables in the empirical model are shown in Table 4. From the results, an initial indication of the direction of association between green finance, green innovation, quality of economic growth and environment and control variables is provided.

Variable	QEG	GF	GI	CO ₂	EC	TO
QEG	1.000					
GF	0.426***	1.000				
GI	0.391***	0.514***	1.000			
CO ₂	-0.287***	-0.214**	-0.176**	1.000		
EC	-0.263***	-0.198**	-0.143*	0.624***	1.000	
TO	0.318***	0.287***	0.354***	-0.192**	-0.117	1.000

Table 4: Correlation Matrix

Note: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

The results indicate that the GF and QEG are positively correlated (0.426), and GI and QEG are also positively correlated (0.391). The positive correlation between GF and GI (0.514) is in line with the notion of the positive relationship between green financial development and innovation. Note that the correlation does not seem to be high enough to be considered a serious problem of collinearity. Energy consumption is positively correlated with CO₂ emissions, while QEG, GF and GI are negatively correlated with CO₂ emissions. There is a positive correlation between trade

openness and QEG, GF and GI. The pattern of the relationships generally conforms to the theory and provides initial validation for the relationships to be analyzed in later dynamic estimation [30].

4.3. Diagnostic Test Results

Table 5 presents the diagnosis results for the dynamic panel specification. The tests suggest that the estimated model meets the basic requirements for successful System-GMM estimation. The AR(1) test is statistically significant but there is no evidence of second-order serial correlation as the AR(2) result is insignificant. The Hansen test also confirms the validity of the instrument set.

Test	Statistic	p-value
AR(1)	-2.87	0.004
AR(2)	-0.91	0.363
Hansen test	24.16	0.287
Wald test	86.42	0.000
Number of instruments	18	—

Table 5: Diagnostic Tests

The result of the insignificant AR(2) suggests that the moment conditions do not suffer from second order serial correlation. Likewise, the validity of the instruments is not rejected by the Hansen test. The Wald statistic is statistically significant showing joint significance of the model. All of these findings support the interpretation of the main dynamic moderation findings.

4.4. Dynamic Moderation Results

The key estimation results from the dynamic moderation model are provided in Table 6. The lagged value of QEG is positive

and significant, suggesting that there is a certain persistence in the quality of economic growth over time. The coefficient of GF is positive and significant, indicating that green finance has a positive impact on the quality of growth. GI also exhibits positive relationship with QEG, suggesting that high levels of green innovation capacity are associated with high quality economic growth. This finding suggests that green innovation enhances the role of green finance in supporting growth quality and supports the proposed moderation hypothesis.

Variables	QEG
QEG (−1)	0.612***
GF	0.184***
GI	0.137**
GF × GI	0.096***
EC	-0.071**
TO	0.083**
Constant	0.214*
Observations	186

Instruments	18
Wald test (p-value)	86.42 (0.000)

Table 6: Dynamic System-GMM Estimation Results

Note: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Figure 2 also shows this result, as the marginal contribution of green finance to QEG increases as the degree of green innovation

increases. This upward trend suggests the innovation capacity enables the green financial resources to provide increased gain for growth quality.

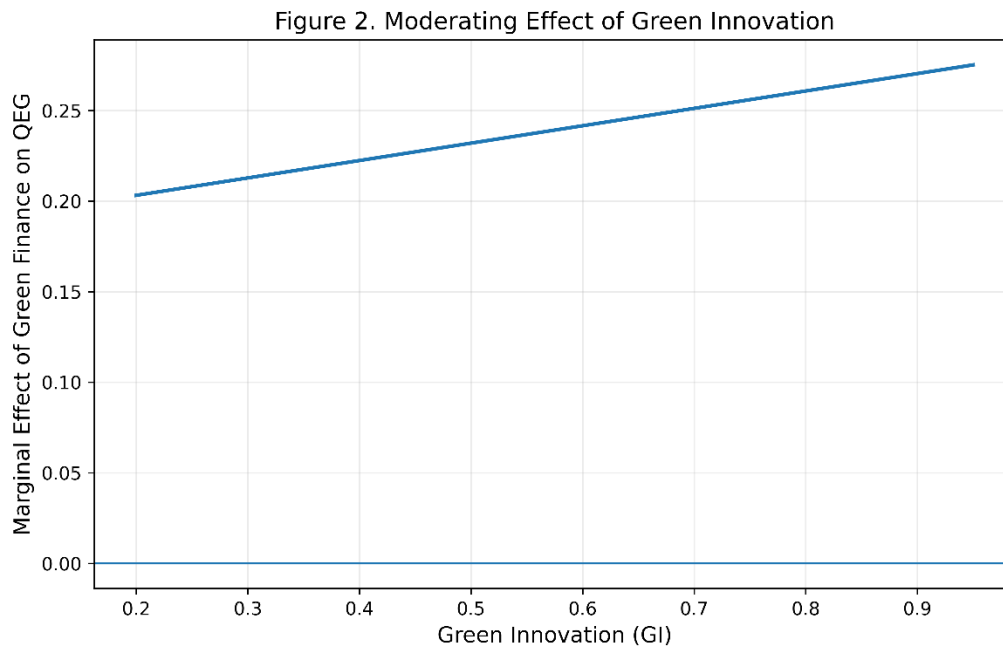


Figure 2: The Moderating Role of Green Innovation Between Green Finance and Quality of Economic Growth.

The negative coefficient of EC indicate that the quality of growth is adversely affected by higher energy consumption and the positive coefficient of TO show that trade openness is positively related to

QEG. The results broadly suggest that innovation environments in which financial resources are invested are important factors in the effectiveness of green finance.

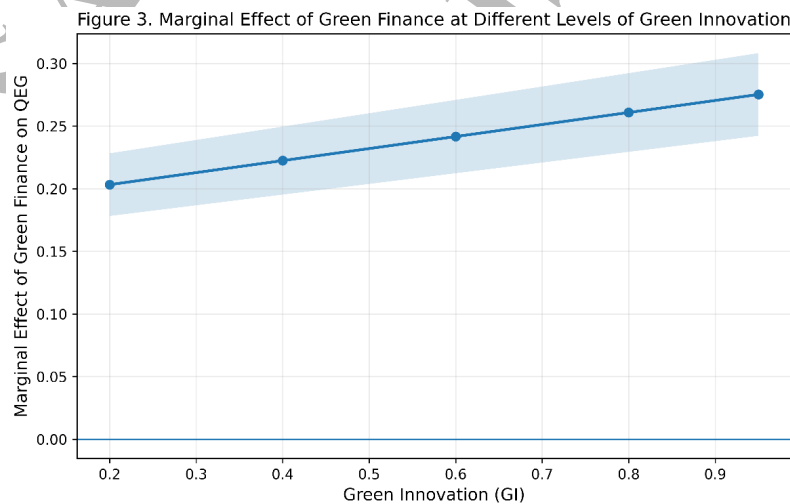


Figure 3: The Quality Of Economic Growth is Predicted For Different Levels of Green Finance And Green Innovatio.

Figure 3 further depicts the effect of green finance, where green innovation is varied at different levels. Results indicate that the positive association between green finance and growth-quality is more pronounced at higher levels of green innovation, implying that a higher innovation capacity has a stronger positive influence on the growth-quality effects of green finance.

4.5. The Study Investigates the Marginal Effects of Green Innovations.

The interaction term validates that green innovation alters the impact of green finance on growth quality. This relationship is explored by looking at the marginal effect of green finance at a range of green innovations. The results show that the impact of GF on QEG is positive and the magnitude of the impact increases with increasing GI. The role of green financing is relatively weak in the context of green innovation at relatively low levels. The green financial resources seem to have a greater effect on improvement

in growth quality as the innovation capacity is strengthened [1]. This indicates that more money is converted to more productive and ecological results with more and better innovation capabilities. The relationship between the marginal effect can be written as:

$$\frac{\partial QEG}{\partial GF} = \beta_1 + \beta_3 GI \quad (5)$$

This finding confirms the moderation hypothesis which is green innovation enhances the positive impact of green finance on economic growth quality. The implications indicate that it is not enough to increase green finance; increasing the productive value of such financial resources by strengthening the innovation ability. The marginal effect is still positive for green finance at all levels of green innovation as see in Figure 4. The upward trend suggests that the green innovation increases the contribution of green finance to economic growth quality.

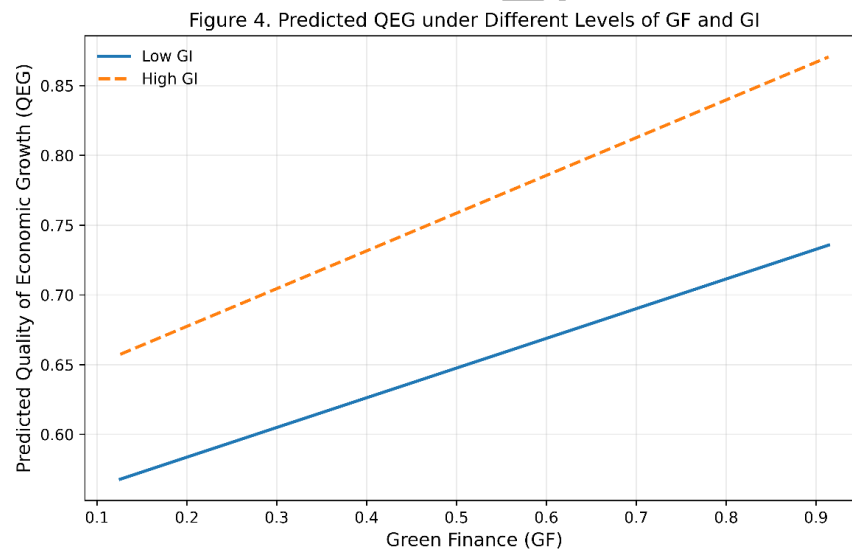


Figure 4: MEGFs for Various Levels of Green Innovation.

4.6. Discussion of Findings

Overall the empirical findings support the main argument of the study. It indicates that the financial activities in the environment can not only help to invest productively but also motivate more efficient use of resources. The positive coefficient of green innovation (GI) further shows that green innovation is important to improve growth quality. Above all, the positive and significant $GF \times GI$ interaction indicates that green innovation reinforces the contribution of green finance in QEG. That is, the positive effects of green finance are more significant in the case of higher innovation capacity. The results reveal that there is a negative relationship between energy consumption (EC) and QEG while a positive relationship between TO and growth quality. These results highlight the importance of considering broader structural conditions when assessing the contribution of green finance [34]. Overall, the evidence suggests that green finance and green innovation are complementary to each other and do not act as separate growth quality drivers, as was the main proposition of the study. Empirical support to the

proposed moderation mechanism has, therefore, been given by the results obtained, which also establishes the need for integrated approach towards finance, innovation and sustainable economic development [35].

5. Conclusion and Implications

5.1. Conclusion

This study explored the connection between green finance and quality of economic growth focusing on the role of green innovation. The results show that green finance has a positive impact on growth quality, and green innovation also helps to support a more efficient growth process. Notably, the interaction effects of green finance and green innovation suggest that the positive effects of green financial development are more pronounced in regions with a greater innovation capacity. The findings also indicate that energy use and trade conditions are also important in determining the quality of growth. On the whole, it seems there is not enough evidence to argue that financial resources can be

used alone to guarantee the improvement of economic growth quality. They are effective to the extent that they are applied in a technological and innovation environment. Thus, green finance can be an even more effective vehicle to support productive, efficient and environmentally responsible economic development when coupled with green innovation.

• Policy Implications

The findings have some practical implications that can be used to enhance the relationship between green finance and economic growth. Firstly, financial institutions should increase funding of investment projects that increase energy efficiency, cleaner production and environmentally friendly technologies. Increased availability of green financial resources can foster investment to activities which create economic value and less environmental stress. Secondly, more focus needs to be placed on green innovation. The effects of financial support are likely to be stronger, where companies and industries have the technological capacity to utilize these resources. Research and development, technology uptake and commercialization of Green technologies policies can thus enhance Green finance. Lastly, financial policies and innovation policies should be done in a co-ordinated fashion instead of in an independent fashion. The co-immersion between green finance and innovation will help to make a more efficient growth process and facilitate the exchange of sustainable economic development.

• Limitations and Future research

Some limitations of this study must be taken into consideration when interpreting studies' results. The analysis is limited to the availability and consistency of data at provincial level, which may be excluding some possible relevant indicators. Further, the chosen timeframe might not reflect a longer-term trend in green financial development and innovation. We can expand the analysis in the future by adding more time and other metrics of green finance and innovation as they become available. Additional research could also investigate whether the relationship found here varies by region, sector or level of economic development. These extensions may help to broaden an understanding of the interplay between financial and technological elements on the nature of economic growth.

Highlights

- Examines the impact of green finance on the quality of economic growth.
- Investigates green innovation as a moderator of the green finance–growth quality relationship.
- Applies dynamic System-GMM estimation to address endogeneity and persistence in growth quality.
- Incorporates CO₂ emissions, energy consumption, and trade openness into the empirical framework.
- Finds that green innovation strengthens the positive effect of green finance on economic growth quality.

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