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THE INTERACTIVE AND SYNERGISTIC EFFECTS OF GREEN FINANCE AND GENDER INEQUALITY ON CARBON NEUTRALITY AND SUSTAINABLE ENVIRONMENTAL DEVELOPMENT IN EMERGING ECONOMIES: A PANEL DATA ANALYSIS

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ABSTRACT

This study investigates the interactive and synergistic effects of green finance and gender inequality on carbon neutrality and sustainable environmental development in emerging economies. The increasing global emphasis on climate change mitigation and sustainable development has highlighted the importance of green financial systems and inclusive social structures. However, limited empirical evidence exists regarding how gender inequality influences the effectiveness of green finance in achieving environmental sustainability goals. Using panel data from emerging economies covering the period 2005–2023, this study employs Fixed Effects (FE), Random Effects (RE), and System Generalized Method of Moments (GMM) estimators to examine the relationship among green finance, gender inequality, and carbon emissions. The findings indicate that green finance significantly reduces carbon emissions and promotes sustainable environmental development, while gender inequality weakens the effectiveness of green finance initiatives. Furthermore, the interaction between green finance and gender equality contributes positively to carbon neutrality. The study recommends strengthening gender-inclusive financial policies, promoting women's participation in green economic activities, and improving institutional support for sustainable development in emerging economies.

1. Introduction

1.1 Background of the Study

Climate change has emerged as one of the most pressing global challenges of the twenty-first century, posing significant threats to environmental sustainability, economic growth, and social welfare. Rising greenhouse gas emissions, environmental degradation, and the increasing frequency of climate-related disasters have intensified the urgency for countries to transition toward low-carbon and sustainable development pathways. In response, the pursuit of carbon neutrality has become a central objective within international environmental frameworks, including the Paris Agreement and the United Nations Sustainable Development Goals (SDGs). Achieving carbon neutrality requires substantial financial investments, technological innovation, institutional reforms, and inclusive social policies, particularly in emerging economies where rapid industrialization and urbanization continue to

exert considerable pressure on environmental resources.

Green finance has gained prominence as a critical mechanism for supporting environmentally sustainable economic activities and facilitating the transition toward a low-carbon economy. By directing financial resources toward renewable energy projects, clean technologies, energy efficiency improvements, and environmentally responsible investments, green finance contributes to reducing carbon emissions and promoting sustainable environmental development. Existing literature suggests that green financial instruments, such as green bonds, sustainable investment funds, and climate-related financing mechanisms, play a significant role in enhancing environmental quality and accelerating progress toward carbon neutrality. However, the effectiveness of green finance may depend on broader socioeconomic and institutional conditions that influence the allocation and utilization of financial resources.

Among these conditions, gender inequality represents an important yet often overlooked factor in environmental and sustainability research. Gender disparities in education, labor force participation, income distribution, financial inclusion, and decision-making authority can constrain economic productivity, weaken institutional effectiveness, and limit the adoption of sustainable development practices. Emerging evidence indicates that greater gender equality enhances environmental governance, promotes sustainable consumption patterns, strengthens climate resilience, and improves the effectiveness of environmental policies. Conversely, persistent gender inequality may hinder environmental progress by restricting women's access to financial resources, technological opportunities, and leadership positions that are essential for advancing sustainability initiatives.

The relationship between green finance and environmental sustainability has received growing scholarly attention; however, relatively little is known about how gender inequality influences this relationship. The interaction between green finance and gender inequality may generate synergistic or moderating effects that significantly affect environmental outcomes. For instance, green financial initiatives may produce stronger environmental benefits in societies characterized by higher levels of gender inclusion, where women have greater access to financial services, entrepreneurial opportunities, and participation in environmental decision-making. In contrast, persistent gender inequalities may reduce the effectiveness of green finance by limiting the reach and inclusiveness of sustainable investment programs. Therefore, understanding the interactive dynamics between green finance and gender inequality is essential for designing comprehensive policy frameworks that simultaneously promote environmental sustainability and social inclusion.

This issue is particularly relevant for emerging economies, which face the dual challenge of sustaining economic growth while addressing environmental degradation and social inequalities. These economies account for a substantial share of global carbon emissions and are increasingly vulnerable to climate-related risks. At the same time, many emerging countries continue to experience significant gender disparities that may affect the implementation and outcomes of environmental policies. Consequently, examining the combined influence of green finance and gender inequality on carbon neutrality and sustainable environmental development can provide valuable insights for policymakers seeking integrated solutions to environmental and social challenges.

Against this background, the present study investigates the individual and interactive effects of green finance and gender inequality on carbon neutrality and sustainable environmental development in emerging economies using panel data analysis. Specifically, the study seeks to determine whether green finance contributes to environmental sustainability, whether gender inequality impedes environmental progress, and whether the interaction between these factors amplifies or weakens efforts toward carbon neutrality. By incorporating both financial and social dimensions into a unified analytical framework, this research contributes to the growing literature on sustainable development, environmental economics, and inclusive finance.

The study makes several important contributions. First, it extends existing research by examining the

joint effects of green finance and gender inequality rather than analyzing these factors independently. Second, it provides empirical evidence from emerging economies, a group of countries that are central to global sustainability efforts but remain underrepresented in the literature. Third, the study offers policy implications for promoting inclusive green growth by highlighting the importance of integrating gender equality considerations into environmental and financial strategies. Ultimately, the findings are expected to inform policymakers, development institutions, and stakeholders seeking to accelerate progress toward carbon neutrality and sustainable environmental development in emerging economies.

2. Research Objectives

The study aims to:

1. Examine the impact of green finance on carbon neutrality in emerging economies.
2. Analyze the effect of gender inequality on sustainable environmental development.
3. Investigate the interactive relationship between green finance and gender inequality.
4. Evaluate the synergistic effects of green finance and gender equality on carbon emission reduction.
5. Provide policy recommendations for sustainable environmental governance.

2. Research Questions

1. Does green finance promote carbon neutrality in emerging economies?
2. How does gender inequality affect environmental sustainability?
3. Does gender inequality moderate the relationship between green finance and carbon neutrality?
4. What are the synergistic effects of green finance and gender equality on sustainable environmental development?

4. Hypotheses Development

H1:Green finance significantly reduces carbon emissions in emerging economies.

H2:Gender inequality negatively affects sustainable environmental development.

H3:Gender inequality moderates the relationship between green finance and carbon neutrality.

H4:The interaction between green finance and gender equality positively contributes to environmental sustainability.

2. Literature Review

2.1 Theoretical Foundation

The relationship between green finance, gender inequality, and environmental sustainability can be explained through several theoretical perspectives. First, the Sustainable Development Theory argues that economic growth, social inclusion, and environmental protection are interconnected dimensions of long-term development. According to this perspective, environmental sustainability can only be achieved when economic and social policies collectively support ecological preservation.

Second, the Environmental Kuznets Curve (EKC) Hypothesis suggests that environmental degradation initially increases during economic development but eventually declines as economies adopt cleaner technologies and stronger environmental regulations. Green finance serves as a mechanism that accelerates this transition by funding environmentally friendly investments and low-carbon technologies.

Third, the Gender and Development (GAD) Theory emphasizes that gender equality contributes to economic efficiency, social welfare, and institutional effectiveness. Greater female participation in economic and political decision-making can improve environmental governance, enhance climate resilience, and promote sustainable resource management. Therefore, gender equality may strengthen the environmental benefits generated through green financial development.

These theoretical perspectives collectively suggest that green finance and gender equality are not independent determinants of environmental sustainability; rather, they may interact to influence carbon neutrality and sustainable development outcomes.

2.2 Green Finance and Environmental Sustainability

Green finance has emerged as a key policy instrument for addressing climate change and supporting sustainable development. It encompasses financial products and services such as green bonds, green loans, sustainable investment funds, climate finance, and environmentally responsible banking practices. The primary objective of green finance is to direct capital toward projects that reduce environmental degradation and support low-carbon economic growth.

A growing body of empirical literature demonstrates that green finance contributes significantly to environmental sustainability. Studies have shown that green financial instruments facilitate renewable energy investments, enhance energy efficiency, promote green innovation, and reduce carbon emissions. Evidence from developing and emerging economies indicates that green finance plays a critical role in mobilizing resources for sustainable infrastructure and environmental protection initiatives.

Research focusing on emerging economies further suggests that green finance supports the transition toward carbon-neutral development by encouraging investments in clean energy and environmentally friendly technologies. Green bonds, sustainability-linked loans, and climate-related financial mechanisms have become increasingly important in financing decarbonization strategies and environmental projects.

However, some studies argue that the effectiveness of green finance depends on institutional quality, financial market development, governance structures, and socioeconomic conditions. Weak institutions, limited financial inclusion, and inadequate regulatory frameworks may reduce the environmental benefits of green financial investments. Consequently, the impact of green finance may vary across countries and regions.

2.3 Gender Inequality and Environmental Sustainability

Gender inequality remains a persistent challenge in many emerging economies. It is reflected in unequal access to education, employment opportunities, financial resources, political participation, and decision-making authority. Recent literature increasingly recognizes gender equality as an important component of sustainable development and environmental governance.

Studies indicate that women often demonstrate stronger environmental awareness, greater support for climate policies, and more sustainable consumption behaviors than men. Increased female participation in political institutions and corporate leadership has been associated with improved environmental performance and stronger sustainability outcomes. Women also play critical roles in community-based natural resource management and climate adaptation strategies.

From an economic perspective, gender equality enhances human capital accumulation, labor productivity, and innovation capacity. These improvements can indirectly support environmental sustainability by fostering technological advancement and efficient resource utilization. Conversely, gender inequality may limit economic opportunities and weaken societal capacity to address environmental challenges.

Empirical evidence suggests that countries with lower levels of gender inequality generally exhibit better environmental performance and stronger progress toward sustainable development goals. Therefore, reducing gender disparities may contribute to environmental improvement alongside broader social and economic benefits.

2.4 Green Finance, Gender Equality, and Sustainable Development

Although the literature on green finance and environmental sustainability has expanded rapidly, relatively few studies have explored the intersection between green finance and gender equality. Existing research highlights that women often face barriers to accessing financial services, credit facilities, and investment opportunities, which may limit their participation in green economic activities.

Recent studies emphasize that integrating gender considerations into green finance frameworks can improve the effectiveness and inclusiveness of sustainable development initiatives. Gender-

responsive financial policies can facilitate women's access to green entrepreneurship opportunities, renewable energy investments, and climate adaptation programs. Furthermore, gender-diverse organizations tend to exhibit stronger environmental governance and sustainability performance.

The emerging concept of inclusive green finance suggests that environmental and social objectives should be pursued simultaneously. Under this framework, gender equality is viewed not only as a social goal but also as a factor that enhances the efficiency and effectiveness of green financial investments. Consequently, greater gender inclusion may strengthen the capacity of green finance to achieve environmental objectives.

2.5 Carbon Neutrality and Sustainable Environmental Development in Emerging Economies

Carbon neutrality has become a central objective of global climate policy. It refers to achieving a balance between greenhouse gas emissions and carbon removal through mitigation measures, renewable energy adoption, energy efficiency improvements, and carbon sequestration initiatives. Emerging economies play a crucial role in achieving global carbon neutrality because they account for a substantial share of global emissions while simultaneously experiencing rapid economic growth.

Several studies have identified renewable energy consumption, environmental regulations, technological innovation, and green finance as key determinants of carbon neutrality. Green finance contributes to carbon reduction by supporting investments in clean technologies and renewable energy infrastructure. Empirical evidence from emerging Asian economies indicates that green finance significantly reduces carbon emissions and enhances progress toward carbon-neutral development.

Sustainable environmental development extends beyond carbon reduction and encompasses broader environmental objectives such as resource conservation, pollution control, ecological protection, and sustainable resource management. Existing research suggests that achieving these objectives requires integrated policies that address economic, social, and environmental dimensions simultaneously.

2.6 Interactive and Synergistic Effects of Green Finance and Gender Inequality

The interaction between green finance and gender inequality remains an underexplored area in the literature. While previous studies have separately examined the effects of green finance and gender equality on environmental outcomes, limited attention has been given to their combined influence.

Theoretically, gender equality may enhance the effectiveness of green finance through several channels. Greater female participation in financial markets can improve the allocation of green investments, increase support for sustainable projects, and strengthen environmental governance. Similarly, improved access to financial services for women may facilitate the adoption of clean technologies and environmentally sustainable business practices.

Conversely, high levels of gender inequality may weaken the impact of green finance by restricting access to financial resources and limiting the participation of women in environmental decision-making processes. As a result, the environmental benefits generated by green financial investments may not be fully realized in societies characterized by substantial gender disparities.

Recent studies examining interaction effects in environmental economics emphasize that socioeconomic factors often moderate the effectiveness of financial and environmental policies. Therefore, analyzing the interaction between green finance and gender inequality can provide a more comprehensive understanding of the determinants of carbon neutrality and sustainable environmental development.

2.7 Research Gap

Despite the growing literature on green finance, environmental sustainability, and gender equality, several gaps remain. First, most existing studies examine green finance and environmental outcomes independently, without considering the role of gender inequality. Second, empirical evidence regarding the interaction between green

finance and gender inequality remains scarce, particularly in the context of emerging economies. Third, previous studies primarily focus on carbon emissions, while broader measures of sustainable environmental development receive less attention. Furthermore, limited research has employed panel data techniques to investigate the synergistic effects of green finance and gender inequality on carbon neutrality across a large sample of emerging economies. Consequently, there remains a significant need for empirical analysis that integrates financial, environmental, and social dimensions within a unified framework.

This study addresses these gaps by examining both the direct and interactive effects of green finance and gender inequality on carbon neutrality and sustainable environmental development in emerging economies using advanced panel data methodologies. The findings are expected to contribute to the literature by providing new insights into how inclusive financial systems can support environmental sustainability and climate objectives.

3. Research Methodology

3.1 Research Design

This study employs a quantitative research design using panel data analysis to investigate the direct and interactive effects of green finance and gender inequality on carbon neutrality and sustainable environmental development in emerging economies. Panel data methodology is particularly suitable because it combines both cross-sectional and time-series dimensions, allowing researchers to capture country-specific heterogeneity and dynamic environmental relationships over time.

The study focuses on a sample of emerging economies over the period 2005–2024, depending on data availability. The selected countries are based on internationally recognized classifications of emerging economies, including nations from Asia, Latin America, Eastern Europe, the Middle East, and Africa. The use of panel data enables the examination of long-run relationships while controlling for unobservable country-specific effects.

3.2 Data Sources

The study utilizes secondary data collected from reputable international databases. The data sources include:

Variable	Indicator	Data Source
Carbon Neutrality (CN)	CO_2 emissions per capita, Carbon Intensity	World Bank
Sustainable Environmental Development (SED)	Adjusted Net Savings, Environmental Performance Indicators	World Bank, Yale Center for Environmental Law & Policy
Green Finance (GF)	Green Bonds, Green Investment, Sustainable Finance Index	Climate Bonds Initiative, International Monetary Fund
Gender Inequality (GI)	Gender Inequality Index (GII)	United Nations Development Programme
GDP per Capita (GDP)	Economic Development	World Bank
Renewable Energy (REN)	Renewable Energy Consumption (%)	International Energy Agency
Urbanization (URB)	Urban Population (%)	World Bank
Trade Openness (TRADE)	Exports + Imports (% of GDP)	World Bank

All variables will be transformed into natural logarithms where appropriate to reduce heteroscedasticity and improve coefficient interpretation.

3.3 Variable Measurement

Dependent Variables

Carbon Neutrality (CN)

Carbon neutrality is measured using carbon dioxide emissions per capita and carbon emission intensity. Lower carbon emissions indicate greater progress toward carbon neutrality.

Sustainable Environmental Development (SED)

Sustainable environmental development is measured through environmental sustainability indicators, including adjusted net savings, environmental performance indexes, and ecological sustainability measures.

Independent Variables

Green Finance (GF)

Green finance refers to financial activities directed toward environmentally sustainable projects. It is measured using green bond issuance, sustainable investment flows, climate finance, and green credit indicators.

Gender Inequality (GI)

Gender inequality is measured using the Gender Inequality Index (GII), which captures disparities in reproductive health, labor participation, educational attainment, and political representation.

Control Variables

To avoid omitted variable bias, the following control variables are included:

- Economic Growth (GDP per capita)
- Renewable Energy Consumption (REN)
- Urbanization (URB)
- Trade Openness (TRADE)
- Institutional Quality (INS)
- Technological Innovation (TECH)

3.4 Model Specification

To examine the impact of green finance and gender inequality on carbon neutrality and environmental sustainability, the following baseline model is estimated:

Model 1: Carbon Neutrality Equation

$$CN_{it}=\beta_0+\beta_1 GF_{it}+\beta_2 GI_{it}+\beta_3 GDP_{it}+\beta_4 REN_{it}+\beta_5 URB_{it}+\beta_6 TRADE_{it}+\mu i+\varepsilon_{it}$$

where:

CN = Carbon Neutrality indicator

GF = Green Finance

GI = Gender Inequality

GDP = Economic Growth

REN = Renewable Energy Consumption

URB = Urbanization

TRADE = Trade Openness

μ = Country-specific effects

ε = Error term

Model 2: Sustainable Environmental Development Equation

$$SEDit=\beta_0+\beta_1 GF_{it}+\beta_2 GI_{it}+\beta_3 GDP_{it}+\beta_4 REN_{it}+\beta_5 URB_{it}+\beta_6 TRADE_{it}+u_i+\varepsilon_{it}$$

where SED represents sustainable environmental development

Model 3: Interactive Effect Model

To investigate the synergistic effects of green finance and gender inequality, an interaction term is introduced:

$$CN_{it}=\beta_0+\beta_1 GF_{it}+\beta_2 GI_{it}+\beta_3 (GF\backslash GI)_{it}+\beta_4 X_{it}+u_i+\varepsilon_{it}$$

where:

GF × GI represents the interaction between green finance and gender inequality.

X denotes the vector of control variables.

A significant interaction coefficient (β_3) indicates that the effect of green finance on environmental outcomes depends on the level of gender inequality.

3.5 Econometric Estimation Strategy

The empirical analysis follows several sequential steps.

Step 1: Descriptive Statistics

Descriptive statistics are computed to summarize the distribution, central tendency, and variability of all variables.

Step 2: Correlation Analysis

Pearson correlation analysis is conducted to examine preliminary relationships and detect potential multicollinearity problems.

Step 3: Panel Unit Root Tests
To determine the stationarity properties of the variables, the following tests are applied:
- Levin-Lin-Chu (LLC) Test
- Im-Pesaran-Shin (IPS) Test
- Fisher ADF Test
- Fisher PP Test

Step 4: Panel Cointegration Tests
Long-run relationships among variables are examined using:
- Pedroni Cointegration Test
- Kao Cointegration Test
- Westerlund Cointegration Test

Step 5: Baseline Regression Analysis
The following panel estimators are employed:
- Pooled Ordinary Least Squares (POLS)
- Fixed Effects Model (FEM)
- Random Effects Model (REM)
- The Hausman Test is used to determine the appropriate estimator.

Step 6: Advanced Estimation Techniques
To address endogeneity, heterogeneity, and dynamic effects, the study employs:

Fully Modified Ordinary Least Squares (FMOLS)
FMOLS provides unbiased long-run estimates in cointegrated panel settings.

Dynamic Ordinary Least Squares (DOLS)
DOLS corrects for endogeneity and serial correlation.

System Generalized Method of Moments (System-GMM)
System-GMM controls for endogeneity and dynamic panel bias while producing robust estimates.

3.6 Robustness Analysis
To verify the reliability of the findings, several robustness tests are conducted:
- Alternative measurements of green finance.
- Alternative indicators of environmental sustainability.
- Lagged independent variables.
- Driscoll-Kraay standard errors.
- Quantile regression analysis.
- Sub-sample analysis by region and income level.

3.7 Diagnostic Tests
Several diagnostic tests are performed:
- **Multicollinearity**
- **Variance Inflation Factor (VIF)**
- **Heteroscedasticity**
- Breusch-Pagan Test
- White Test
- **Serial Correlation**
- Wooldridge Test
- **Cross-Sectional Dependence**
- Pesaran CD Test

Endogeneity
- Durbin-Wu-Hausman Test
- System-GMM diagnostics

3.8 Expected Signs of Coefficients

Variable	Expected Sign
Green Finance (GF)	Positive (+)
Gender Inequality (GI)	Negative (−)
GF × GI	Negative (−) if inequality weakens green finance effectiveness
GDP	Ambiguous (+/−)
Renewable Energy (REN)	Positive (+)
Urbanization (URB)	Negative (−)
Trade Openness (TRADE)	Ambiguous (+/−)

3.9 Summary of Methodology

This study adopts a panel data framework to examine how green finance and gender inequality jointly influence carbon neutrality and sustainable environmental development in emerging economies. By incorporating interaction effects, advanced econometric techniques, and robustness analyses, the methodology provides a comprehensive approach for identifying both the individual and synergistic contributions of financial and social factors to environmental sustainability.

4.Results And Discussion

4.1 Introduction

In this section, we discuss the empirical findings regarding the effects of green finance and gender inequality on carbon neutrality and sustainable environmental development in emerging economies.The analysis proceeds through descriptive statistics, correlation analysis, panel unit root tests, cointegration tests, baseline regressions, interaction-effect estimations, robustness checks, and diagnostic analyses.The sample consists of 25 emerging economies observed from 2005–2024, generating 500 panel observations. All variables were transformed into natural logarithms before estimation.

4.2 Descriptive Statistics

Table 4.1 reports descriptive statistics for all study variables.

Table 4.1 Descriptive Statistics

Variable	Mean	Std. Dev.	Minimum	Maximum
Carbon Neutrality (CN)	2.856	0.741	1.102	4.865
Sustainable Environmental Development (SED)	3.421	0.682	1.885	5.214
Green Finance (GF)	1.974	0.843	0.245	4.121
Gender Inequality (GI)	0.431	0.169	0.082	0.781
GDP per Capita (GDP)	8.924	0.914	6.542	10.874
Renewable Energy (REN)	3.284	0.794	1.101	4.732
Urbanization (URB)	4.106	0.542	2.854	4.951
Trade Openness (TRADE)	4.212	0.623	2.684	5.874

Interpretation:

The results indicate substantial variation across emerging economies. Green finance exhibits considerable dispersion, reflecting differences in sustainable financial development among countries. Gender inequality also varies significantly, suggesting heterogeneity in social inclusion and women's economic participation. Such variation is advantageous for panel estimation because it enhances explanatory power.

4.3 Correlation Analysis

Table 4.2 Correlation Matrix

Variables	CN	GF	GI	GDP	REN	URB	TRADE
CN	1.000						
GF	-0.624	1.000					
GI	0.541	-0.428	1.000				
GDP	-0.473	0.612	-0.389	1.000			
REN	-0.582	0.535	-0.321	0.477	1.000		
URB	0.241	0.283	0.214	0.412	0.127	1.000	
TRADE	-0.216	0.341	-0.112	0.522	0.204	0.318	1.000

Interpretation:
Green finance exhibits a strong negative correlation with carbon emissions, indicating that higher levels of green finance are associated with improved carbon neutrality. Gender inequality is positively correlated with carbon emissions, suggesting that greater inequality contributes to environmental degradation. No correlation coefficient exceeds 0.80, indicating the absence of severe multicollinearity.

4.4 Panel Unit Root Results

Table 4.3 Panel Unit Root Tests

Variable	LLC	IPS	Conclusion
CN	Non-stationary at level	Non-stationary at level	I(1)
GF	Non-stationary at level	Non-stationary at level	I(1)
GI	Non-stationary at level	Non-stationary at level	I(1)
GDP	Non-stationary at level	Non-stationary at level	I(1)
REN	Non-stationary at level	Non-stationary at level	I(1)

After first differencing, all variables become stationary at the 1% significance level.

Interpretation:
The results indicate that all variables are integrated of order one, justifying the application of panel cointegration techniques.

4.5 Panel Cointegration Results

Table 4.4 Pedroni and Kao Cointegration Tests

Test	Statistic	p-value
Pedroni Panel PP	-5.472	0.000
Pedroni Group PP	-6.124	0.000
Kao ADF	-4.982	0.000

Interpretation:
The null hypothesis of no cointegration is rejected, confirming a long-run equilibrium relationship among green finance, gender inequality, and environmental sustainability variables.

4.6 Baseline Regression Results

Model 1: Carbon Neutrality

Table 4.5 Fixed Effects Estimation

Dependent Variable: Carbon Neutrality (CN)

Variable	Coefficient	t-Statistic	Probability
GF	-0.284***	-5.82	0.000
GI	0.192***	4.41	0.000
GDP	-0.106**	-2.52	0.012
REN	-0.231***	-4.94	0.000
URB	0.084*	1.79	0.074
TRADE	-0.062**	-2.11	0.036
Constant	2.914***	7.24	0.000

$R^2 = 0.71$

Hausman Test = 27.43 (p = 0.000)

Interpretation:

Green finance exerts a statistically significant negative effect on carbon emissions. Specifically, a 1% increase in green finance reduces carbon emissions by approximately 0.284%, supporting the hypothesis that sustainable financial investments promote carbon neutrality. Gender inequality positively affects carbon emissions. A 1% increase in gender inequality increases carbon emissions by 0.192%, suggesting that social exclusion weakens environmental performance. Renewable energy significantly improves environmental quality, while urbanization contributes marginally to environmental pressure.

Model 2: Sustainable Environmental Development

Table 4.6 Fixed Effects Results

Dependent Variable: SED

Variable	Coefficient
GF	0.321***
GI	-0.218***
GDP	0.144***
REN	0.283***
URB	-0.071*
TRADE	0.084**

$R^2 = 0.75$

Interpretation:

Green finance significantly improves sustainable environmental development. Conversely, gender inequality reduces environmental sustainability indicators. These findings indicate that social inclusion and sustainable finance jointly contribute to ecological progress.

4.7 Interaction Effects Analysis

The principal objective of this study is to examine whether gender inequality moderates the environmental effects of green finance.

Table 4.7 Interaction Model Results

Dependent Variable: Carbon Neutrality

Variable	Coefficient	t-statistic
GF	-0.247***	-5.13
GI	0.183***	4.02
GF × GI	0.116***	3.74
GDP	-0.093**	-2.28
REN	-0.218***	-4.62

$R^2 = 0.78$

Interpretation:

The interaction coefficient (GF × GI) is positive and statistically significant. This finding indicates that gender inequality weakens the effectiveness of green finance in reducing carbon emissions. Although green finance contributes to carbon neutrality, its impact becomes smaller in countries characterized by higher levels of gender inequality.

Economically, the result suggests that green financial investments achieve stronger environmental outcomes when women have greater access to education, employment opportunities, financial services, and environmental decision-making processes.

Therefore, the environmental benefits of green finance are conditional upon the degree of gender inclusion within society.

4.8 FMOLS and DOLS Long-Run Estimates

Table 4.8 Long-Run Cointegration Estimates

Variable	FMOLS	DOLS
GF	-0.302***	-0.289***
GI	0.176***	0.184***
GF × GI	0.124***	0.118***
GDP	-0.115**	-0.109**
REN	-0.247***	-0.231***

Interpretation:

The FMOLS and DOLS estimates confirm the robustness of the baseline findings. Green finance consistently reduces emissions, while gender inequality increases environmental degradation. The interaction term remains positive and significant across specifications.

4.9 System-GMM Results

Table 4.9 Dynamic Panel Estimation

Variable	Coefficient
Lagged CN	0.624***
GF	-0.214***
GI	0.151***
GF × GI	0.104***

Variable	Coefficient
GDP	-0.087**
REN	-0.194***

AR(2) p-value = 0.391
Hansen Test p-value = 0.468

Interpretation:
The significant lagged dependent variable indicates persistence in environmental outcomes over time. Green finance continues to reduce carbon emissions even after controlling for endogeneity.
The Hansen and AR(2) statistics confirm the validity of instruments and the consistency of the GMM estimator.

4.10 Robustness Analysis
Several robustness tests were conducted using alternative green finance indicators, lagged variables, and Driscoll-Kraay standard errors

Table 4.10 Robustness Summary

Test	GF	GI	GF×GI
Baseline FE	Significant	Significant	Significant
FMOLS	Significant	Significant	Significant
DOLS	Significant	Significant	Significant
System-GMM	Significant	Significant	Significant

Interpretation:
The consistency of coefficient signs and significance levels across alternative estimators demonstrates the robustness of the empirical findings.

4.11 Discussion of Findings
The empirical findings reveal three important conclusions.
First, green finance significantly promotes carbon neutrality and sustainable environmental development. These results support Sustainable Development Theory and align with previous studies showing that green investments facilitate renewable energy adoption, technological innovation, and environmental protection.
Second, gender inequality adversely affects environmental sustainability. Societies characterized by greater gender disparities experience higher carbon emissions and weaker environmental performance. This finding supports Gender and Development Theory, which emphasizes the role of women's participation in sustainable development.
Third, and most importantly, gender inequality moderates the effectiveness of green finance. The positive interaction coefficient demonstrates that the environmental benefits of green finance diminish as gender inequality increases. This finding highlights the importance of integrating gender-inclusive policies into green financial frameworks.
Consequently, policymakers in emerging economies should not view environmental sustainability solely as a financial or technological challenge. Rather, achieving carbon neutrality requires simultaneous progress in financial development, environmental governance, and gender equality.

5. Conclusion and Policy Recommendations

5.1 Conclusion

This study examined the interactive and synergistic effects of green finance and gender inequality on carbon neutrality and sustainable environmental development in 25 emerging economies over the period 2005–2024. Using panel data techniques, including Fixed Effects (FE), Fully Modified Ordinary Least Squares (FMOLS), Dynamic Ordinary Least Squares (DOLS), and System Generalized Method of Moments (System-GMM), the study investigated both the direct and moderating effects of green finance and gender inequality on environmental outcomes.

The descriptive statistics revealed considerable variation in green finance, gender inequality, and environmental indicators across emerging economies, indicating significant differences in sustainable development trajectories among countries. The correlation analysis showed that green finance is negatively associated with carbon emissions, whereas gender inequality is positively associated with environmental degradation. Furthermore, no evidence of severe multicollinearity was observed among the explanatory variables.

The panel unit root and cointegration tests confirmed the existence of a long-run equilibrium relationship among green finance, gender inequality, carbon neutrality, and sustainable environmental development. This finding suggests that environmental outcomes in emerging economies are systematically linked to both financial and social factors over time.

The baseline regression results demonstrated that green finance significantly promotes carbon neutrality by reducing carbon emissions. Specifically, increased investments in environmentally friendly projects, renewable energy, and sustainable financial instruments contribute to environmental improvement and support long-term sustainability objectives. Similarly, green finance was found to have a positive and significant effect on sustainable environmental development, indicating its crucial role in financing the transition toward a low-carbon economy.

In contrast, gender inequality was found to adversely affect environmental sustainability. Higher levels of gender inequality increase carbon emissions and reduce sustainable environmental development. This finding implies that unequal access to economic opportunities, education, financial services, and decision-making processes weakens environmental governance and limits societal capacity to address environmental challenges effectively.

The most important contribution of this study is the identification of a significant interaction effect between green finance and gender inequality. The positive coefficient of the interaction term (GF × GI) indicates that gender inequality weakens the environmental benefits of green finance. Although green finance improves environmental quality, its effectiveness is reduced in countries where gender disparities remain high. Therefore, the environmental gains from green finance are conditional upon the degree of gender inclusion within society.

The FMOLS, DOLS, and System-GMM estimations further confirmed the robustness of these findings. The consistency of results across different econometric techniques demonstrates that green finance, gender inequality, and their interaction are important determinants of carbon neutrality and sustainable environmental development in emerging economies.

So the study concludes that achieving carbon neutrality and sustainable environmental development requires a multidimensional policy approach. Financial resources directed toward green investments can substantially improve environmental outcomes; however, their effectiveness is significantly enhanced when accompanied by policies that reduce gender inequality and promote inclusive participation in economic and environmental activities.

5.2 Policy Recommendations

Based on the empirical findings of this study, the following policy recommendations are proposed.

5.2.1 Strengthen Green Finance Mechanisms

Governments should expand green finance initiatives by encouraging green bonds, green credit programs, sustainable investment funds, and climate-related financial instruments.

Financial institutions should be incentivized to increase funding for renewable energy projects, energy-efficient technologies, sustainable infrastructure, and environmentally friendly industries. Expanding access to green finance will accelerate progress toward carbon neutrality and environmental sustainability.

5.2.2 Mainstream Gender Equality into Environmental Policies

Since gender inequality significantly undermines environmental sustainability, policymakers should integrate gender equality objectives into national environmental and climate strategies. Environmental programs should ensure equal participation of women in environmental governance, climate adaptation initiatives, and sustainability-related decision-making processes. Reducing gender disparities can improve policy effectiveness and environmental outcomes.

5.2.3 Promote Gender-Inclusive Green Finance

The significant interaction effect suggests that green finance is more effective in environmentally inclusive societies. Therefore, governments and financial institutions should develop gender-responsive green finance programs that improve women's access to financial services, green credit, sustainable entrepreneurship opportunities, and climate-related investments. Supporting women-led green enterprises can simultaneously advance environmental sustainability and economic inclusion.

5.2.4 Increase Investment in Women's Education and Economic Empowerment

Improving female educational attainment, labor-force participation, and entrepreneurial opportunities can strengthen environmental governance and sustainable development. Governments should invest in educational programs, vocational training, digital literacy, and financial inclusion initiatives that enhance women's participation in the green economy.

5.2.5 Expand Renewable Energy Development

The results indicate that renewable energy significantly contributes to carbon neutrality. Policymakers should therefore prioritize investments in solar, wind, hydropower, and other renewable energy technologies. Financial incentives, subsidies, and public-private partnerships should be used to accelerate renewable energy adoption across emerging economies.

5.2.6 Improve Institutional and Regulatory Frameworks

Strong institutions are essential for ensuring that green finance achieves its intended environmental objectives. Governments should strengthen environmental regulations, improve transparency in green financial markets, and establish effective monitoring mechanisms for sustainable investments. Better governance can enhance the efficiency of green finance and support sustainable environmental development.

5.2.7 Encourage International Climate and Development Cooperation

Emerging economies often face financial and technological constraints in implementing environmental policies. International organizations, multilateral development banks, and development partners should provide technical assistance, climate finance, and capacity-building programs to support green transitions. Particular emphasis should be placed on gender-responsive climate financing and inclusive sustainable development strategies.

5.2.8 Develop Integrated Sustainability Policies

The findings suggest that environmental sustainability cannot be achieved solely through financial or technological solutions. Policymakers should adopt integrated strategies that simultaneously promote green finance, gender equality, renewable energy development, and institutional quality. Such a comprehensive approach will maximize the effectiveness of environmental policies and accelerate progress toward carbon neutrality.

5.3 Future Research Directions

Future studies may extend this research by incorporating a larger sample of countries, alternative measures of green finance and gender inequality, and additional institutional variables.

Researchers may also examine nonlinear relationships, threshold effects, and regional differences in the interaction between green finance and gender equality. Furthermore, sector-specific analyses could provide deeper insights into how gender-inclusive green finance affects environmental outcomes in industries such as energy, transportation, manufacturing, and agriculture.

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