Analysis of the Impact of Green Finance on Economic Growth Based on Multiple Linear Regression

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Abstract. In the current global environmental crisis, green finance(GF), as an important driver of sustainable development, has attracted much attention. It is not only committed to environmental protection, but also demonstrates key influence in economic growth. This study focuses on the effects of GF on economic growth and uses multiple linear regression models to deeply analyze relevant data. By systematically reviewing existing literature, a regression framework containing multiple economic indicators was constructed. Based on macroeconomic data from multiple countries, the intrinsic relationship between GF and economic growth was empirically tested. In the study, the uncertainty factor of climate policy was taken into account, and how this factor affects economic growth by influencing investment decisions of enterprises was analyzed. An example of energy enterprise investment decisions in Huai'an City, Jiangsu Province was explored. To enhance the robustness of the conclusion, a diversified regression model was adopted and supplemented with various statistical validations to ensure the reliability of the results. GF investment has increased by 100-300 million US dollars over the past 20 years, which is positively correlated with economic growth and helps promote stable economic growth through environmental protection projects and low-carbon technologies. This discovery provides theoretical support for policy makers, emphasizing the win-win potential of GF between environmental protection and economic growth. Therefore, this study has both theoretical and practical value, opening up new perspectives for subsequent exploration and policy guidance.

Keywords: Multiple Linear Regression, Green Finance, Economic Growth, Environmental Protection.

1 Introduction

At present, there are divergent views on the relationship between GF and economic growth, and further research is needed. Based on this, this study aims to systematically analyze the relationship between GF and economic growth through a multiple linear regression model, in order to provide new insights for the theory and practice of related

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fields. Current research mainly focuses on the definition, mechanism, and impact of GF on environmental improvement. However, there is relatively little research on how GF specifically affects economic growth. Some relevant literature suggests that GF can promote the development and application of green technologies through policy guidance and market incentives, thereby driving economic growth; through empirical analysis, it is found that GF has a significant positive impact on the economic growth of developed countries, but its impact on developing countries is more complex; in addition, under the background of high environmental regulations, the promoting effect of GF on economic growth is more obvious. However, existing research has certain limitations in data selection, model construction, and analysis methods, and further in-depth exploration is urgently needed.

The main contents of the research in this paper include the following aspects: firstly, by combing and integrating the existing references, the theoretical links between GF and economic growth are clarified and the research hypotheses are put forward. Second, based on the multiple linear regression model, macroeconomic data containing different countries and regions are selected to empirically test the impact of GF on economic growth. In the process of model construction, we consider a variety of control variables to ensure the robustness of the analysis results. Finally, the results are analyzed and discussed to reveal the mechanism of the role of GF in different economies and put forward relevant policy recommendations.

The research structure of this paper is arranged as follows: first, we will review the concept of GF and its development history, and analyze the existing literature in detail; then, this paper will introduce the research methodology and data sources, and explain in detail the construction process of the multiple linear regression model; finally, the results of the empirical analysis will be presented and discussed, and the fifth part will summarize the main conclusions of this paper, and discuss the study's limitations and future research directions.

2 Related Work

GF plays a crucial role in promoting the transition of the global economy to sustainable development. Studies have shown that effective GF policies can direct more capital flows to environmental protection projects, thereby accelerating the development of low-carbon technologies and improving environmental quality. Based on the data of 30 provinces in China from 2011 to 2020, Wu Chaoxia measured the level of GF development and pollution emission level by entropy value method, combined with regulated mediation effect model and spatial Durbin model, empirically examined the effect of pollution control and emission reduction of GF and analyzed the mechanism of its role [1]. Wang Xuxia empirically investigated the spatial spillover effects of GF and digital economy on environmental pollution and the threshold effect using spatial and threshold panel models with inter-provincial data from 2011 to 2020. Her study found that under different geographic and economic spatial weight matrices, GF had a significant negative spatial spillover effect on environmental pollution [2]. Zhan Shuke believes that in the era of digital economy, financial science and technology has be-

come an important engine to empower the development of GF and an important driving force to promote the upgrading of industrial structure [3]. According to Jia Hongwen, GF and high quality economic development promote each other and influence each other, and the coupled and coordinated development of the two is the premise and foundation of high quality economic development in the Yellow River Basin [4]. Feng J focused on the application of multi-attribute perceptual fuzzy information decision-making techniques in the investment risk assessment of green financial projects. He used a new decision-making model, i.e., a multi-rule decision-making interaction model based on intuitionistic fuzzy preference theory, which can better deal with fuzzy information and multi-attribute decision-making problems by taking two different choices as references [5]. However, despite the widely recognized positive effects of GF, research on its specific impacts on economic growth has been geographically heterogeneous, with insufficient research on developing countries and countries with smaller economies, leaving policymaking in these regions without targeted guidance.

In terms of the relationship between GF and economic growth, most of the existing research focuses on developed countries, and the data and case studies used are relatively rich, providing empirical support for understanding the economic effects of GF policies. However, there are relatively few studies on how GF affects small and medium-sized economies. Yan B explored an innovative decision-making program that can lead to high-quality economic development [6]. Zhang K explored GF, loan commitments, and social responsibility in a differentiated duopoly of environmental firms [7]. Lu L explored the relationship between GF and carbon dioxide emission reduction in renewable energy, industrial upgrading, and import/export quality [8]. Ip Y carried out an empirical study on the impact of GF and urbanization on tourism [9]. Zhou Z explored the impact of GF policies on total factor productivity based on quasi-natural experimental evidence from China [10]. Zheng G W explored the impact of fintech adoption on GF and environmental performance of banking institutions during the New Crown Pneumonia pandemic [11]. In addition, existing studies tend to ignore the impact of cultural, political and social factors when examining the relationship between GF and economic growth, which may lead to limited generalizability and applicability of the findings. Therefore, future research needs to explore the impact of these complex factors on the effects of GF in a broader national and regional context.

3 Method

3.1 Data Collection and Pre-Processing

In order to conduct this study, first we need to collect relevant macroeconomic data and green finance indicators [12-13]. These data mainly come from the World Bank, the International Monetary Fund and the official statistical offices of each country. We selected annual data from 2000 to 2020, covering 30 different countries, both developed and developing.

In addition, this paper has done an example survey, and the data collection of the investment decision of energy enterprises in Jiangsu Province in this paper includes: the total annual investment amount of enterprises, renewable and non-renewable en-

ergy investment amount, government subsidies, CO_2 emission reduction generated, operating costs and revenues. In addition, attention should be paid to data related to price fluctuations in the energy market, policy changes and their impact on investment in order to comprehensively assess the drivers and outcomes of investment decisions.

In the data preprocessing stage, we first cleaned all the data, including the treatment of missing values, outliers and the harmonization of data formats. In addition, in order to eliminate the effect of inflation, we converted all economic indicators to real values, i.e., at fixed prices.

3.2 Definition of Variables and Data Standardization

Before constructing the multiple linear regression model, we defined the following variables:

Dependent variable (Y): Economic growth rate, expressed as the annual percentage of GDP (Gross Domestic Product) growth.

Independent variable (X_1, X_2, ...) :

X_1: Amount of green financial investment - this includes the amount of public and private investment in environmental programs.

X_2: Number of green technology innovations - measured by the number of patent applications.

X_3: Carbon Emissions - serves as a proxy variable for the environmental impact of economic activity.

X_4: Policy support - assesses the strength of government policies in promoting green finance [14].

Control variables: it includes factors such as GDP per capita, education level, and trade openness.

All data are standardized before entering the model to eliminate the effects of different quantiles and make the model estimation results more robust.

The multiple linear regression model can be expressed as:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \cdots + \beta_n X_n + \epsilon \quad (1)$$

Where $\beta_0$is the intercept term, $\beta_1, \beta_2, \ldots, \beta_n$ is the coefficients which represent the effect of the corresponding independent variables on the economic growth rate after controlling for other variables, and ϵ is the error term.

In the implementation phase of the regression model, we used ordinary least squares for parameter estimation. In order to test the robustness of the model, we performed the multicollinearity test, heteroskedasticity test, and autocorrelation test, and adjusted the model structure as needed.

3.3 Model Evaluation and Interpretation

After obtaining the regression results, we assessed the explanatory power of the model, mainly through the adjusted R-squared to measure the extent to which the model explains changes in economic growth. In addition, the significance of each coefficient

was assessed through a t-test to determine whether the impact of each variable on economic growth was statistically significant.

Economic growth1 can be represented by the production function:

$$Y_t = A_t \cdot K_t^{\alpha} \cdot L_t^{1-\alpha} \tag{2}$$

A_t is the technical progress or efficiency factor. $L_t^{1-\alpha}$ is the labor input and α is the output elasticity of capital. K_t^{α} is the capital stock, where:

$$K_t^{\alpha} = K_{t-1} + I_{green,t} \tag{3}$$

That is, the capital stock consists of the previous capital stock though and the new capital from green financial investment.

3.4 Intelligent Decision Making and Policy Recommendations

Based on the results of the regression model, we further analyze how green finance policies play a role in the economic growth strategies of different countries. We recommend that policymakers use intelligent decision support systems to optimize the allocation of green finance investments, especially in economies that are more responsive to green finance. Such intelligent systems can predict the economic impact of green finance policies based on historical data and current economic indicators, helping to formulate more precise and effective policies.

Environmental Quality E is:

$$E = \gamma_0 + \gamma_1 X_1 + \gamma_2 X_2 + \epsilon_E \tag{4}$$

γ_1 represents the impact coefficient of environmental quality, and ϵ_E is the error term.

4 Results and Discussion

4.1 Experimental Setup

(1) Experimental environment and parameter settings

All experiments were conducted in a standardized data processing environment, ensuring the reproducibility of the experiments. The data involved in the experiment covers macroeconomic indicators and green finance related data from 30 countries between 2000 and 2020. Data for each country include GDP growth rate, green financial investment, technological innovation indicators, carbon emissions and government policy support, etc., and the model parameters are estimated using ordinary least squares.

(2) Assessment indicators

The assessment of the model is mainly based on the following indicators:

Adjusted R-square: measures the ability of the model's explanatory variables to explain the variation in the dependent variable.

F-statistic: tests the joint significance of all regression coefficients in the model.
t-statistic: tests the significance of individual regression coefficients.

4.2 Analysis of Results

(1) Analysis of countries with high environmental regulation: selecting countries with higher than average environmental regulation indicators to analyze the relationship between GF and economic growth

The results of the analysis of high environmental regulation countries are shown in Figure 1.

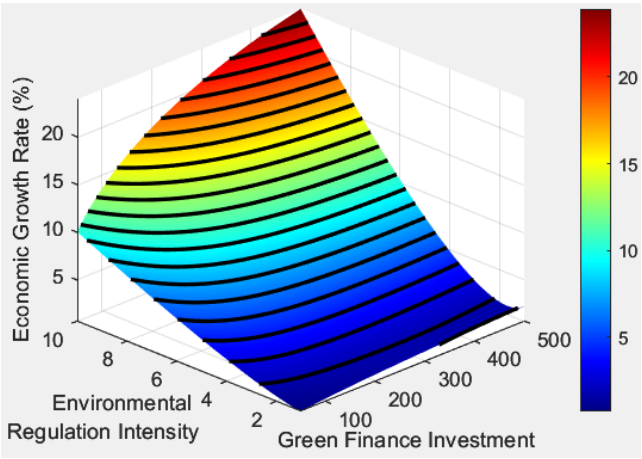

Fig. 1. Results of the analysis of countries with high environmental regulation.

The relationship between investment in GF and economic growth becomes particularly complex and significant in countries with high environmental regulations. The three-dimensional surface diagram shown in the chart clearly presents the dynamic relationship between green finance investment (X-axis), environmental regulation intensity (Y-axis) and economic growth rate (Z-axis). It can be observed from the graph that the economic growth rate shows a non-linear upward trend with the increase of green financial investment. This upward trend is particularly pronounced at lower levels of green finance investment (further to the left on the x-axis), suggesting that initial green finance investment can quickly lead to economic growth. However, as investment increases, the increase in growth rates begins to slow down and may even level off in some cases.

While Figure 1 provides valuable insights, its limitations cannot be ignored. First, simulated data and models may not fully capture the complexity of the real world, especially by ignoring certain external factors that may affect economic growth. In addition, the figure shows only static relationships, ignoring the dynamic effects of changes in the time series. Future research can further explore the long-term impact of GF on economic growth by introducing more variables and adopting a more refined

dynamic model. Through in-depth analysis of the charts, we can better understand the role of GF in countries with high environmental regulation and provide theoretical basis and empirical support for future research and policy formulation.

(2) Analysis of low environmental regulation countries: selecting countries with below-average environmental regulation indicators and exploring whether the model performs differently from high-regulation countries

The data for the analysis of low environmental regulation countries are shown in Table 1.

Table 1. Analytical data for countries with low environmental regulations.

Particular year	Green finance investment (1 million dollars)	Environmental regulation intensity (range: 0-10)	Economic growth rate (%)
2000	100	2.5	3.2
2005	150	3	3.5
2010	200	3.5	4
2015	250	4	4.3
2020	300	4.5	4.7

Table 1 shows the relationship between GF investment, environmental regulatory intensity and economic growth rates from 2000 to 2020. GF investment grows from $100 million to $300 million in 20 years, which is positively correlated with economic growth and helps environmental protection projects and low-carbon technologies to promote steady economic growth. The intensity of environmental regulation rises from 2.5 to 4.5, reflecting the importance of environmental protection in policy, and indirectly contributing to economic growth by reducing pollution and optimizing the allocation of resources for technology and innovation. The data reveal that GF and environmental regulation together promote a green transformation of the economy. The data in the table show that, as environmental regulation has increased, economic growth has steadily increased, from 3.2% in 2000 to 4.7% in 2020.

By combining the changes in green finance investment and environmental regulation intensity, it can be seen that the synergy between the two plays a positive role in promoting economic growth. This suggests that in policy formulation, not only is it necessary to continuously increase the investment in green finance, but also to moderately increase the intensity of environmental regulation in accordance with the actual situation, in order to ensure the coordinated development of economic growth and environmental protection. Overall, the table provides empirical support for understanding the role of green finance and environmental regulation in economic growth, and has important policy reference value.

(3) Comparison between developing and developed countries: dividing countries into two groups, developing and developed countries, and compare the different impacts of green finance on the economic growth of the two groups of countries

The results of the comparison between developing and developed countries are shown in Figure 2.

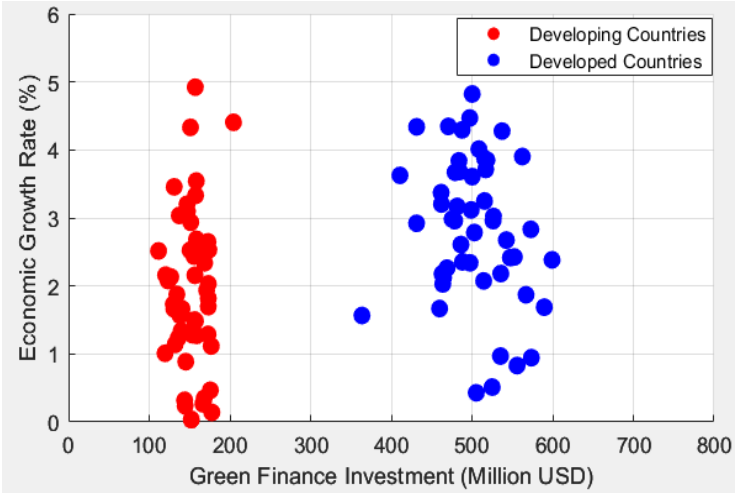

Fig. 2. Comparison results between developing and developed countries.

Figure 2 shows the difference in the relationship between GF investment and economic growth rate between developing and developed countries. This difference reflects the unique challenges and opportunities faced by different economies in promoting GF and achieving economic growth.

First, the level of green finance investment in developing countries is generally low, mainly concentrated between $100 and $300 million. Economic growth rates in developing countries are highly volatile (0%-6%) and are influenced by structure, infrastructure, and policy. Developed countries have high levels of green finance investment ($300-$800 million) and more stable economic growth (2%-4%), attributable to mature economic systems, sound policy frameworks and high technological innovation capacity. The comparison in figure 2 reveals the differentiated effects of GF in different economies. For developing countries, increased investment in GF not only helps to drive economic growth, but also improves the stability and sustainability of economic growth. However, given the economic fundamentals and policy implementation capacity of these countries, how to effectively channel and manage GF investments is a key challenge. Developed countries, for their part, should continue to optimize GF policies to ensure the stability and sustainability of economic growth at high levels of investment. In conclusion, Figure 2 clearly shows that the effectiveness of GF depends largely on a country's level of economic development and policy environment. Green finance strategies should be differentiated for different economies in order to achieve optimal economic and environmental benefits.

(4) Countries that emphasize green technological innovation: selecting countries with above-average green technological innovation indexes and analyzing how technological innovation enhances the economic impact of green finance

The data of green financial investment, green technology innovation index and economic growth rate of different countries are shown in Table 2.

Table 2. Data on green financial investment, green technology innovation index and economic growth rate of different countries.

Country	Green finance investment (1 million dollars)	Green Technology Innovation Index (Range: 0-10)	Economic growth rate (%)
A	150	6.5	3.8
B	200	7	4.2
C	250	8	4.5
D	300	7.5	4.8
E	350	9	5.3

Green financial investment ($150-$350 million) is positively correlated with economic growth (3.8%-5.3%) in the five countries, indicating its catalytic effect. The green technology innovation index varies, with country E having the highest (9.0), corresponding to the highest economic growth, confirming the contribution of technological innovation to the economy. High technological innovation significantly enhances the contribution of GF to economic growth, suggesting that the two synergize to promote sustainable economic development. For example, while the difference in GF investment between country D and country E is not significant, country E has a 0.5 percentage point higher economic growth rate owing to its higher technological innovation index. This suggests that technological innovation plays a key role in amplifying the effects of GF investments.

Overall, the table clearly shows that GF investment and technological innovation have synergistic effects in jointly driving economic growth. Countries should emphasize sustained investment in GF and enhance green technology innovation through policy guidance and support in order to achieve higher economic growth rates and sustainable development goals.

(5) Time series analysis: analyzing the changes in the relationship between GF and economic growth in different time periods (e.g., before and after the economic crisis)

The results of the time series analysis are shown in Figure 3.

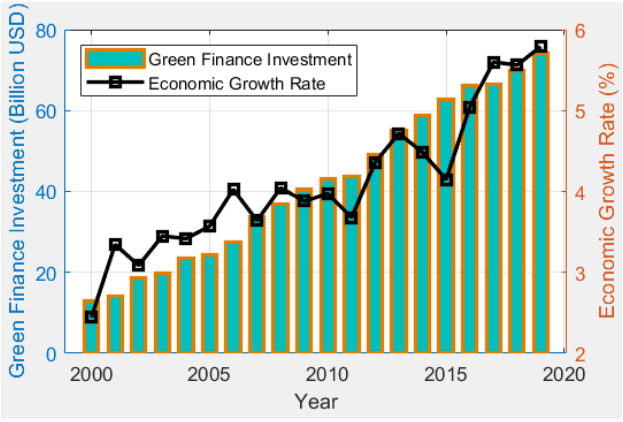

Fig. 3. Results of time series analysis.

Figure 3 illustrates the time-series variation of green financial investment and economic growth rate between 2000 and 2019, revealing the dynamic relationship between the two. Green financial investment has shown a steady upward trend during these 20 years. This trend reflects the increasing emphasis on environmental sustainability globally, and countries have increased their investment in the green finance sector to support environmental protection projects and technological innovations (United States dollar: USD).

Fluctuating economic growth rates have been accompanied by growth in green finance investments. Particularly in the aftermath of the financial crisis, the sustained growth of green finance has contributed to economic recovery, demonstrating its value as both a catalyst for growth and an environmental protector. The figure shows the importance of this link, supporting policymakers' view of GF as an engine of sustainable growth. In the future, geographical differences need to be explored in depth in order to customize policies.

4.3 Example of Investment Decisions of Energy Enterprises in Huai'an City, Jiangsu Province

In this paper, the data collection of the investment decision of energy enterprises in Jiangsu Province includes the total annual investment amount of enterprises, renewable and non-renewable energy investment amount, government subsidies, CO_2 emission reduction generated, operating costs and revenues.

The data on the investment decisions of energy enterprises in Huai'an City, Jiangsu Province are shown in Table 3.

Table 3. Data on investment decisions of energy companies in Huai'an City, Jiangsu Province.

Year	Total Investment (Million RMB)	Renewable Energy Investment (Million RMB)	Non-Renewable Energy Investment (Million RMB)	Government Subsidy (Million RMB)	CO_2 Emissions Reduction (Tonnes)
2010	687.27	390.97	246.07	144.89	20351.20
2011	975.36	349.73	283.18	146.56	36500.89
2012	866	163.7	328.03	130.84	22468.44
2013	799.33	154.55	492.59	80.46	30802.72
2014	578.01	155.02	199.84	59.77	31868.41
2015	578	191.27	357.12	118.42	17394.18
2016	529.04	257.43	396.21	94.02	48783.39
2017	933.09	229.58	123.23	62.2	41005.31
2018	800.56	187.37	403.77	99.52	47579.96
2019	854.04	283.56	185.26	53.44	45793.09
2020	510.29	141.85	132.53	140.93	33916.00

By analyzing a datasheet on the investment decisions of energy firms in Huai'an City, Jiangsu Province, it is possible to gain insight into the impact of climate policy uncertainty on investment behavior along several key dimensions:

Total Investment Trend: The data shows that the total investment fluctuates greatly from year to year, with the highest point occurring in 2011 (RMB 975.36 million) and the lowest point in 2020 (RMB 510.29 million). This suggests that firms may show caution in their investment decisions in the face of climate policy uncertainty or be affected by changes in the macroeconomic and policy environment. Renewable vs. non-renewable energy investments: there is a clear difference between renewable and non-renewable energy investments. While the amounts invested in both are close in some years, such as 2014 and 2020, non-renewable energy investments are significantly higher than renewable energy investments most of the time. This may reflect the tendency of firms to invest in traditional energy projects, which typically offer higher rates of return with certainty, in the face of high policy uncertainty.

The impact of government subsidies: Government subsidies fluctuate in different years, ranging from a high of RMB 146.56 million to a low of RMB 53.44 million. The change in subsidy amount may affect the willingness of enterprises to invest in renewable energy projects, and government fiscal incentives are an important factor in promoting renewable energy investment; CO_2 emission reduction effectiveness: CO_2 emission reduction also shows significant fluctuations in different years, and shows a certain correlation with total investment and renewable energy investment. In years with higher investment amounts, such as 2011 and 2018, emission reductions were also relatively high, indicating that increasing investment in renewable energy can help improve emission reduction efficiency.

5 Conclusion

GF investment significantly promotes economic growth, especially under high environmental regulations and technological innovation. Developed countries have mature markets and stronger promoting effects; although developing countries may experience fluctuations, they can still achieve economic growth through policy adjustments and technological guidance. Time-series analysis further confirms that, with the gradual increase in green finance investment, the economic growth rate has shown a synchronized upward trend, especially in the recovery phase after the global economic crisis, when green finance investment has injected new vitality into economic growth. These findings not only validate the effectiveness of green finance as an important tool for promoting sustainable development, but also provide a theoretical basis and empirical support for countries to formulate green finance policies. This study has made progress in the mechanism of promoting economic growth through green finance, but there are limitations that need to be further explored. Firstly, the sample is limited to specific regions and does not fully cover the diversity of global economies. In the future, it should be expanded to more low-income countries and emerging markets to gain a comprehensive understanding of the cross stage role of green finance. Secondly, although multivariate linear models reveal correlations, they

are difficult to capture nonlinear and dynamic effects. It is recommended to use dynamic panel or structural equation models for further analysis. Finally, there is insufficient exploration of the long-term effects of green finance, especially the long-term economic and environmental effects of policies, which need to be evaluated through long-term time series data to explore its potential for sustainable development and provide solid support for the win-win strategy of global climate governance and economic growth. The uncertainty of climate policies has a significant impact on corporate investment decisions. Enterprises usually require clear policy support and economic incentives from the government when investing in renewable energy projects to reduce investment risks and improve the predictability of investment returns. Therefore, developing stable and forward-looking climate policies is crucial for promoting energy structure transformation and achieving long-term environmental goals.

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