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Research on the Impact of Green Finance on the Development of Industrial Upgrading and Transformation under the Dual Carbon Goal

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Abstract: *Driven by the goal of "carbon peaking and carbon neutrality", the development of green finance has become an important means of promoting sustainable economic development nationwide and contributing to the transition towards an environmentally friendly industrial structure. This study utilizes quarterly data from 2017 to 2023 and employs a Vector Autoregression (VAR) model to explore the relationship between key indicators such as green credit, green insurance, and green investment, and the industrial structure. The findings reveal that while green finance has made some progress in China, its short-term impact on industrial transformation is mixed. In the long term, green finance gradually exerts a positive influence on the optimization of the industrial structure, although these changes are primarily driven by internal factors. This study proposes several strategic recommendations, including strengthening green finance policies, improving green credit mechanisms, and increasing investment in green technologies, encouraging industry participation, and regularly monitoring and evaluating policy impacts. These measures are crucial for effectively leveraging green finance to promote industrial upgrading and contribute to China's dual carbon goals, thereby fostering sustainable economic development.*

Keywords: *Green Finance, Carbon Peaking, Carbon Neutrality, Vector Autoregression (VAR) Model, Green Credit, Green Insurance, Green Investment, Industrial Structure, Sustainable Economic Development*

1. Introduction

During the 2016 G20 Hangzhou Summit, the topic of green finance received extensive attention from the international community, and the meeting adopted the G20 Green Finance Synthesis Report drafted by China, which highlights the key role of green finance in promoting economic growth. In order to promote the optimization and upgrading of industrial structure, the stable and rational development of green finance is crucial. Compared with traditional financial models, green finance places special emphasis on lowering greenhouse gas emissions, reducing environmental pollution and working to improve the efficiency of energy and resource use, with the core objective of protecting and adding value to natural capital while emphasizing long-term sustainable economic development. It has been three years since China announced its 'dual-carbon' goal on September 22, 2020, aiming to peak carbon emissions by 2030 and achieve carbon neutrality by 2060. Achieving these goals will require significant investment in green transformation and technological innovation, as well as the mobilization of capital from all sectors of society, allowing the market to play a decisive role in resource allocation. The financial sector plays a crucial role in this transformation process by providing not only financial support for industrial transformation but also effective means of risk management. Therefore, an in-depth understanding of the intrinsic connection between green finance and industrial restructuring is of great theoretical value and practical significance for promoting the rapid development of green finance and the optimization and upgrading of industrial structure.

In the context of increasing constraints posed by environmental and resource limitations, the academic community has gradually begun to explore sustainable development pathways. Achieving the transition from traditional high-pollution, high-energy-consumption industries to low-carbon, green industries largely depends on the support of financial instruments. Consequently, an increasing number of researchers are applying financial strategies to the fields of environmental protection and sustainable development. Many studies have extensively explored the interrelationship between green finance and industrial transformation. However, most research in China has predominantly focused on the impact of green finance on regional differences and specific influencing factors, with limited studies examining the

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impact of green finance on industrial upgrading and transformation from a temporal perspective. This paper comprehensively and objectively measures the level of green finance development in China since 2017 from the perspectives of green credit, green insurance, and green investment. It analyzes the mechanisms, duration, and contribution of green finance to industrial structure upgrading, aiming to identify the intrinsic links between green finance and industrial structure adjustment in China. This provides significant theoretical value and practical significance for promoting the rapid development of green finance and the optimization and upgrading of industrial structures[1-3].

2. Literature Review

The relationship between financial development and industrial upgrading has been a focal point of economic research. Goldsmith (1969) pioneered the exploration of how financial system development is integral to economic structural transformation and industrial upgrading. Building on this foundation, Mckinnon (1973) examined how the advancement of financial markets facilitates economic growth and structural change, emphasizing the critical role of financial asset allocation in optimizing resource distribution and promoting industrial upgrading. Shaw (1973) further contributed to this discourse by introducing the concept of financial deepening, elucidating how the diversification of financial intermediaries and assets drives economic development and industrial transformation. Empirical evidence supporting these theoretical perspectives was provided by King and Levine (1993), who demonstrated through their analysis that financial development influences economic growth and productivity, particularly through the efficient allocation of financial assets that affects industrial structure. Levine (1997), in a comprehensive review, synthesized both theoretical and empirical research on the link between financial development and economic growth, offering an extensive literature review that highlights how financial development underpins industrial upgrading and structural change. Collectively, these studies underscore the pivotal role of financial systems in facilitating industrial transformation, setting the stage for the analysis of green finance's impact on industrial upgrading in the context of China's dual carbon goals.

Recent research highlights the significant impact of green finance on industrial upgrading in China, with a focus on regional variations and specific influencing factors. Wang and Wang (2021) employed grey relational analysis and system GMM models, demonstrating that green finance significantly promotes industrial structure upgrading, particularly in the tertiary sector. Their study highlighted regional differences, showing that green finance has a stronger impact in the eastern regions compared to the central and western regions. This effect is further facilitated by factors such as human resources, research innovation, government support, market development, and urban growth. Contrastingly, Zhang (2023) found that green finance's influence is more pronounced in the central and western regions compared to the eastern regions. Zhang's research revealed that the effects of green finance are partly achieved through reductions in carbon emissions, promoting greener and more sustainable industrial practices, and noted that positive changes can extend to surrounding areas, fostering regional development. Wang and Li (2022) also observed significant impacts of green finance in central China, identifying technological progress as a crucial driver of industrial upgrading. They noted that oppenness, government support, and human capital significantly affect industrial upgrading, while the urbanization rate had a minimal impact. Similarly, Wang and Wang (2021) also emphasized that human resources, innovation, government role, market development and urban growth have promoted industrial upgrading to some extent.

In addition, Zhao et al. (2024) employed a fixed-effects model to examine the positive impact of green finance and green technology innovation on industrial upgrading, particularly in regions with higher concentrations of population and economic activity and more developed technology markets. And Hu and Zhang (2022) argue that, beyond technological innovation, foreign investment and infrastructure improvement are also critical channels for promoting industrial optimization. They note that larger economies or regions with closer central-local coordination and cooperation derive greater economic benefits from green finance. Both studies underscore the importance of regional characteristics in maximizing the effectiveness of green finance for industrial transformation. Researchers also recognize that while green finance initiatives can promote positive changes, there are significant challenges that can limit their effectiveness. Gu et al. (2021) highlight issues such as uneven development, information asymmetry, and inadequate regulation as factors contributing to a decline in green finance efficiency, stressing the need for improved oversight and enhanced environmental governance to support industrial transformation. Similarly, Hu and Zhang (2022) note that while green finance reform pilot zones have generally facilitated positive effects, they have also impeded further industrial optimization and may negatively impact surrounding regions economically or environmentally[4-6].

3. Empirical results and analysis

3.1 Variable Selection and Modeling

3.1.1 Variable Selection

Considering that the green credit data of the five major banks have been published since 2009 and there are missing data in 2016 in terms of insurance and investment, this study selected national quarterly data for the period from 2017 to 2023 for analysis. Data sources include China Statistical Yearbook, China Insurance Yearbook, China Environmental Statistics Yearbook, and social responsibility and financial reports published by the five major banks. The results of the statistical descriptive analysis of all sample variables are presented in Table 1.

Table 1: Basic statistical description of variables

Variable Name	Unit	Observed Value	Mean Value	Standard Deviation	Minimum value	Maximum value
IS	%	28	90.88	2.63	86.53	93.11
GE	%	28	5.32	0.26	0.77	6.45
GI	%	28	2.67	0.34	2.04	3.27
GR	%	28	1.61	0.21	1.46	1.83

Note: The data in the table are calculated from excel tables.

This study applied logarithmic transformation to the selected variables to reduce potential heteroscedasticity in the data. The transformed data do not alter the relationships between the variables but make the distribution of the data closer to a normal distribution, thereby improving the stability and accuracy of the model. Specifically, the logarithmically transformed data for IS is denoted as lnIS, for GE as lnGE, for GI as lnGI, and for GR as lnGR.

3.1.2 Modeling

The vector autoregressive (VAR) model is an unstructured dynamic multivariate model introduced by Sims in 1980. This model is mainly applied to forecasting time series datasets and assessing the role of random disturbances on the variables of the whole system. The VAR model describes the dynamic relationships of the variables in the system through a series of autoregressive equations, which are expressed in mathematical form as:

$$Yt=C+\Phi_1Y_{t-1}+\Phi_2Y_{t-2}+...\Phi_pY_{t-p}+\varepsilon_t,\ t=1,\ 2,\ ...28 \tag{1}$$

where: Yt is a set of n×1-dimensional time series vector, C is an n×1-dimensional constant vector, Φ_t is an n×n-dimensional matrix of autoregressive coefficients to be estimated, ε_t is an n×1-dimensional vector of white noise and satisfies the following relationship: $E(\varepsilon_t)=0$, $E(\varepsilon_t\varepsilon_t')=\Omega$, $E(\varepsilon_t\varepsilon_s')=0$, for $t\neq s$.

Based on this model, it is possible to handle multivariate time series data and capture the dynamic relationships between variables, thereby revealing the impact of green finance on industrial upgrading. And the VAR model adapts to changing trends without needing a priori causal assumptions. Its strong forecasting capabilities support predictions and decision-making. Additionally, its widespread use in economics and finance lends it high interpretative power and credibility[7-9].

3.2 Empirical Analysis

3.2.1 Unit Root Test

The unit root test ensures the stationarity of time series data, thereby avoiding spurious regression issues and ensuring the reliability of model analysis and forecasting. The Augmented Dickey-Fuller (ADF) test was used in this study and its results are detailed in Table 2. By analyzing Table 2, it can be observed that the variables LnIS LnGE, LnGI and LnGR exhibit non-stationary properties, which means that they all contain unit roots. After first order differencing of the series, these variables are relabelled as LnIS(-1), LnGE(-1), LnGI(-1) and LnGR(-1) respectively. The absolute values of the ADF statistics for these variables exceeded the absolute values of the corresponding critical values at 95% confidence intervals, thus confirming that all of these variables have shifted to a steady state under these conditions.

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Table 2: Results of ADF test

Variables	ADF test	ADF critical value (5%)	Pron.*	Smoothness
LnIS	-0.678	-3.023	0.8331	uneven
LnIS(-1)	-13.021	-3.022	0.0000	steady
LnGE	-1.110	-3.001	0.6971	uneven
LnGE(-1)	-4.821	-3.005	0.0013	steady
LnGI	-1.873	-3.001	0.3421	uneven
LnGI(-1)	-4.512	-3.005	0.0023	steady
LnGR	-1.614	-3.031	0.4661	uneven
LnGR(-1)	-4.769	-3.005	0.0012	steady

Prob.* to denote the value of the probability that the variable will occur if the original hypothesis is accepted.

3.2.2 Cointegration Test

In this study, we utilized the Johansen test to determine if there is a long-term stable relationship among the variables. Prior to conducting the cointegration test, it is essential to ascertain the optimal number of lags for the VAR model. By applying the AIC and SC to evaluate the unrestricted VAR model, we identified that the optimal lag order is set at 1. The specific results of the cointegration test are presented in Table 3.

Table 3: Results of Johansen Test

Null hypothesis	Characteristic value	Trace statistic	The critical value of 0.05	Prob.**
None*	0.8363	64.5042	47.8561	0.0007
At most 1	0.3355	24.6873	29.7971	0.1729
At most 2*	0.3302	15.6962	15.4947	0.0466
At most 3*	0.2686	6.8806	3.8415	0.0087

Note: ***, **, * correspond to significance levels of 1%, 5%, and 10%, respectively.

Based on the information displayed in Table 3, the trace test results indicate that there is at least one cointegration relationship between the transformation and upgrading of the industrial structure and green finance. This implies that there is a long-term interconnection and the ability to achieve an equilibrium state among the four variables of industrial transformation and upgrading indicators, green credit, green insurance, and green investment, thus meeting the conditions for constructing the VAR model.

3.2.3 VAR model estimation

Given that the existence of at least one cointegration relationship is confirmed among the four variables, namely LnIS, LnGE, LnGI and LnGR, we can include them all as endogenous variables for consideration and thus construct a multivariate vector autoregression (VAR) model based on the theory of cointegration. By estimating the parameters of the model using Eviews 7.0 software, we obtained the relevant results of the VAR model as shown below:

$$\begin{bmatrix} LnIS \\ LnGE \\ LnGI \\ LnGR \end{bmatrix} = \begin{bmatrix} 4.7710 \\ 2.6900 \\ -0.0277 \\ 0.2910 \end{bmatrix} + \begin{bmatrix} 0.0832 & -0.047 & 0.0095 & -0.54 \\ 0.0093 & 0.0046 & -0.1415 & 0.9432 \\ 0.8235 & -0.0046 & 0.1156 & -0.1284 \\ -0.4152 & 0.0120 & 0.5334 & -0.0776 \end{bmatrix} \begin{bmatrix} LnIS_{t-i} \\ LnGE_{t-i} \\ LnGI_{t-i} \\ LnGR_{t-i} \end{bmatrix} + \varepsilon$$

The fitting effects of the four groups of autoregressive equations show some differences, with fitting indices of 0.956, 0.867, 0.863 and 0.651, respectively, of which the first three groups show a higher quality of fit, while the fourth group shows a lower degree of fit. The analytical results of the VAR model reveal the close connection between the transformation and upgrading of the industrial structure (LnIS) and its state in the previous period, indicating that every 1 percentage point of improvement in the of the previous period's transformation progress will lead to an increase of 0.0832 percentage points in the current period. In addition, the growth of green credit (LnGE) and green investment (LnGR) presents certain constraints on the transformation of industrial structure (LnIS). In contrast, the growth of green insurance (LnGI) has a positive impact on the transformation (LnIS), with each 1 percentage point increase contributing to a 0.0095 percentage point increase in the current

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period's transformation.

3.2.4 Stability test of the model

In order to ensure the validity of the impulse response analysis, the VAR model was tested for stability. It can be observed through Figure 1 that all characteristic roots in the model fall inside the unit circle, which implies that the model is stable and thus impulse response analysis based on the VAR model can be carried out.

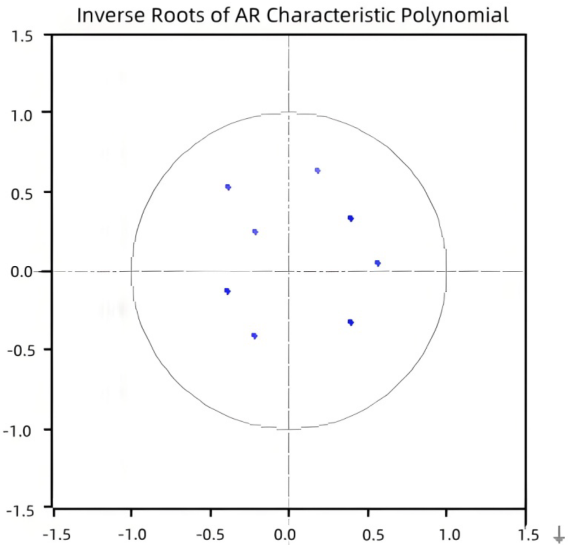

Figure 1: Plot of model stability test

3.3 Impulse Response Function

The analytical method used in this paper is a VAR model with a response period of 10, and its impulse response function is presented in Figure 2:

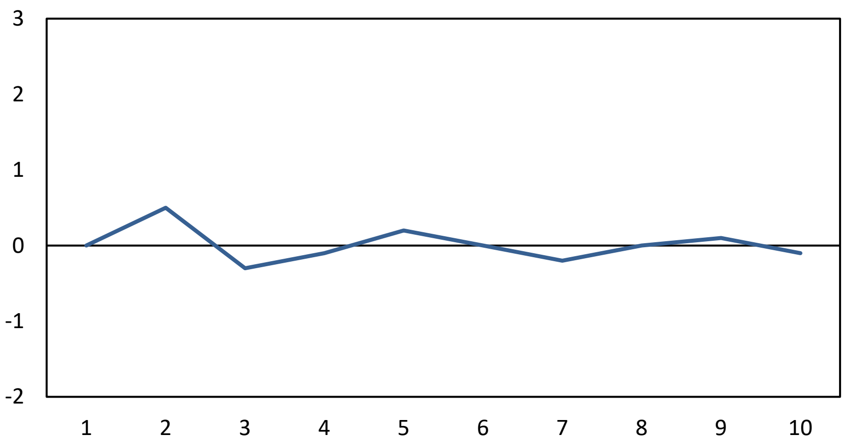

Figure 2: Response of LnIS to LnGR

By analyzing the data in Fig. 2, it can be observed that under the impact of green investment (LnGR), the optimization and upgrading of industrial structure (LnIS) shows an upward trend at the initial stage, i.e., period 1, and the change is positive. In period 2, the upward trend reaches a peak, and then gradually falls back to the bottom in period 3, and then rises again, and finally enters a relatively stable fluctuation range. In the short term, the optimization and upgrading of industrial structure (LnIS) shows a positive response to green investment (LnGR), indicating that green investment (LnGR) has a facilitating effect on the upgrading of industrial structure (LnIS). However, in the long run, the promotion effect of green investment (LnGR) on industrial structure upgrading (LnGR) is gradually weakening. Since the impulse response of industrial structure (LnIS) to green credit (LnGE) and green insurance (LnGI) is not significant, it is not discussed in detail in this paper[10-13].

3.4 Variance decomposition

The study adopts the variance decomposition method to quantitatively analyze the transformation and upgrading of industrial structure as well as the influencing factors of the four key variables related to it, namely, green credit, insurance and investment, and the detailed results are listed in Table 4.

Table 4: Results of variance decomposition

period	Variance decomposition of LnIS			
	LnIS	LnGE	LnGI	LnGR
1	99.51	0.00	0.49	0.00
2	96.82	2.62	0.55	0.01
3	97.24	2.19	0.47	0.09
4	96.31	3.14	0.46	0.09
5	96.62	2.86	0.43	0.10
6	96.42	3.08	0.41	0.10
7	96.40	3.11	0.39	0.10
8	96.31	3.20	0.39	0.10
9	96.29	3.23	0.39	0.10
10	96.33	3.20	0.38	0.10

According to the variance decomposition data shown in Table 4, the change of the industrial structure itself (LnIS) is the main source of fluctuations in its transformation and upgrading. Over the observed 10 periods, the contribution rate of its own shocks consistently exceeds 96%, while the contribution of green finance to this transformation process is less than 4%. In particular, green insurance (LnGI) and green investment (LnGR) have relatively minor impacts on the transformation of the industrial structure (LnIS), contributing less than 1%. Although the contribution of green credit （LnGE) shows an upward trend, the overall impact of green finance on changes in the industrial structure (LnIS) remains limited. This reflects that the current role of green finance in promoting industrial structural change is not yet obvious and may be related to the scale and maturity of green finance in China. However, in the long run, it is expected that the positive impact of green finance on industrial structure transformation will gradually increase.

4. Conclusion and Policy Recommendations

This study empirically investigates China's quarterly data from 2017 to 2023 using the VAR model combined with the variance decomposition technique in order to explore the role of green finance in promoting industrial structure upgrading. The results of the analysis reveal that (1) during the period from 2017 to 2023, China has made certain progress in industrial structure adjustment and green finance development. (2) In the short term, although green credit and green investment from the previous period can constrain the current industrial structure transformation, green insurance demonstrates a promoting effect. At the initial stage, green investment has a significant positive impact on industrial upgrading, although its long-term effects are somewhat diminished. This suggests that green investment has a certain short-term driving force in optimizing industrial structure and can stimulate the adjustment and upgrading of the industrial structure. (3) In the long term, green finance continues to play a gradually positive role in enhancing industrial structure optimization. Although the fluctuations in industrial structure transformation are primarily driven by internal factors and the current impact of green finance is limited, its long-term potential for promotion should not be underestimated.

Based on these findings, this study proposes the following strategic recommendations: First, strengthening green finance policies is crucial. The study underscores the need for a more robust policy framework that supports green credit, green insurance, and green investment. Policymakers should consider developing and implementing targeted policies that provide incentives for green finance activities. This could include offering tax benefits, subsidies, or other financial incentives to institutions and companies engaged in environmentally friendly projects. Second, enhancing green credit mechanisms is essential. The analysis indicates that green credit has a significant, though constrained, impact on industrial transformation. To improve its effectiveness, the government should encourage banks to expand their green loan portfolios and simplify the application processes for green loans.

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Additionally, increasing transparency and reporting requirements for green credit can help track its impact and encourage greater participation from financial institutions. Third, promoting green insurance solutions should be a priority. The study finds that green insurance has a positive effect on industrial upgrading (Goshu Desalegn, 2023). To maximize this benefit, policies should be introduced to foster the development and uptake of green insurance products. This might involve creating more comprehensive insurance products for environmental risks and providing incentives for companies to adopt these products (Hu et al., 2020).

Fourth, increasing investment in green technologies is necessary. Although green investment shows a short-term positive impact on industrial structure upgrading, its long-term effects are diminishing. To sustain and enhance these benefits, the government should focus on boosting funding for research and development in green technologies. Public-private partnerships and grants for innovative green projects can also stimulate more investment in this area (Zhang & Wang, 2019). Fifth, encouraging industry participation is important. Engaging stakeholders in the development and implementation of green finance policies ensures that these policies align with industry needs and receive broad support (Zhang et al., 2021). Creating platforms for dialogue between policymakers, financial institutions, and industrial leaders can facilitate this process. Lastly, monitoring and evaluating policy impact regularly is vital. Establishing a framework for ongoing assessment can help ensure that green finance policies continue to meet their objectives and contribute to sustainable industrial transformation. This approach allows for timely adjustments and improvements, enhancing the overall effectiveness of the policies. By implementing these recommendations, China can better leverage green finance to drive industrial upgrading and contribute to achieving its dual carbon goals, fostering sustainable economic development.

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