Empirical Analysis of Dynamic Relationship Between Green Economy and Green Finance by VAR Model

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Abstract. With the development of China's economy, some problems such as ecological imbalance, serious pollution of the environment, low utilization of natural resources and so on, are followed. Green economy and green finance are very necessary to alleviate these problems. Based on the annual data of China's green finance and green economy from 2004 to 2017, we build a VAR model to empirically analyze the dynamic relationship between green economy and green finance. The empirical results indicate that increasing investment in green finance positively affects the development of green economy; simultaneously, green economy also has a certain degree of impact on green finance, which has a restraining effect in the early stage, but with the growth of time, green economy is also important to green finance. This study explores the interaction mechanism between green finance and green economy, which is important to promote ecological civilization construction, green economic development and sustainable development.

Keywords: Green finance · Green economy · VAR model

1 Introduction

China has been exploring various new ways of development for decades to solve the problems of ecological imbalance and environmental pollution to ensure sustainable and stable economic growth on the premise of building a good ecological environment. The measures of sustainable development can make the natural resources be used reasonably and the waste of resources can be reduced obviously. After decades of continuous exploration and perfection of the way to solve the problems of ecology, environment and resources in China, although a good system has not yet been formed, the development direction of green finance and green economy in China is becoming more and more clear. Green finance contributes to the growth of green economy and green economy can also promote the upgrading of green finance. Therefore, the research on the relevance between green economy and green finance is very necessary to promote the sustainable development of economy and society and ecological environment protection, and has theoretical and practical guiding values.

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This paper constructs a VAR model, uses impulse function analysis and variance analysis to empirically analyze the relationship between green economy and green finance. The innovation of this paper lies in the analysis of the interaction between green finance and green economy by estimating the VAR model; the dynamic impact characteristics of green economy and green finance are depicted by using impulse corresponding function; and the contribution of green economy and green finance to each other is analyzed by variance decomposition.

2 Literature Review

2.1 Green Economy

The concept of a "green economy" originated from the Green Economy Blueprint, a 1989 book by David W. Pearce, a British environmental economist. In the book, the author believed that economic development should be within the acceptable limits of the natural environment and human beings and should not lead to ecological environmental crisis and social and economic collapse due to the blind pursuit of economic growth [1, 2]. Bohong Huang (2020) defined green economy as an economic model that uses high and new technologies to reduce resource waste, realize recycling, and then promote the coordinated development of ecological benefits, economic benefits and social benefits [3]. He et al. (2019) believed that green economy is essentially a sustainable development integrating ecology and economy, which is conducive to improving high energy consumption, adjusting economic structure and promoting stable economic growth [4].

2.2 Green Finance

On August 31, 2016, the Guiding Opinions on Building a Green Financial System officially defined green finance for the first time as economic activities supporting environmental protection and improving resource utilization or financial services provided to projects in this related field [5]. Zhang et al. (2019), in view of existing studies, understood green finance as investment financing conducive to environment and sustainable development, mainly including climate finance and carbon finance [6]. Wang et al. (2016) believed that green finance is an innovative financial model combining economic interests with environmental protection and pays more attention to ecological environmental benefits and green environmental protection industry [7]. Different from traditional finance, green finance pays close attention to the green issues in economic development and tends to lead the capital chain to the green industry.

2.3 Green Economy and Green Finance

Domestic and foreign scholars have deeply discussed green economy and green finance from two aspects of theoretical research and empirical research. In terms of theoretical research, Jinqiang Yan and Xiaoyong Yang (2018) considered that the key to the construction of green economy system lies in the innovation of green technology, and green finance runs through the whole process of green technology innovation. Therefore, they

believed that it was necessary to adhere to the green finance as the center, strengthen and coordinate the green financial system to promote the development of green economy [8]. Jianhua Zhu et al. (2019) pointed out that the environmental protection principle emphasized by green finance is consistent with the sustainable development followed by circular economy. The two complement each other and develop harmoniously. In other words, the sustainable growth of circular economy depends on the positive support of green finance. In turn, the continuous growth of circular economy promotes the creation and upgrading of green finance [9]. Owen et al. (2018) focused on the contribution of the public sector in solving the financing gap and proposed the need to establish a financial ecosystem to ensure financing support for investment in the context of considering low-carbon and environmental protection [10]. Taghizadeh-Hesary (2019) advocated the establishment of green credit guarantee scheme (GCGS) to improve the tax revenue effect generated by green energy supply, reduce the uncertainty of green finance, and promote more green investment, so as to promote the realization of sustainable development goals [11].

In empirical research, Zhang et al. (2020) used the sample data of Non-financial private enterprises in China from 2012 to 2017 to prove that green innovation can effectively broaden the limits of corporate financing considering the interests of all parties [12]. Based on the financial data from 2000 to 2018, Shao et al. (2020) constructed the green finance development index, and used vector error correction model (VECM) empirical analysis to conclude that green finance can reduce carbon intensity [13]. Xiaohong Dong and Yong Fu (2018) empirically analyzed the spatial dynamic evolution process of the coupling development of green finance and green economy by using the coupling degree model and the data of 2008–2016 in China. The research results showed that the coupling development of green economy and green finance is highly coordinated [14].

Through the research and analysis of domestic and foreign theoretical and empirical research results on green economy and green finance, it is shown that scholars have conducted in-depth research on the link between green finance and green economy. However, there is little research on the dynamic correlation within green finance and green economy, and have not yet described the dynamic impact characteristics between them. Therefore, this paper uses VAR model, impulse response function and variance decomposition analysis to empirically analyze the dynamic relationship between green economy and green finance, and reveal the dynamic characteristics of their interaction.

3 Sample Selection and Model Construction

3.1 Variable Selection

1. Environmental protection investment (INV). Based on the previous literature, environmental protection investment is used to measure the level of green investment, and green investment reflects the degree of financial support for green development, and then to measure the development level of green finance. Therefore, on the basis of reference to relevant literature, this paper chooses environmental protection investment (INV) as the representative of green financial indicators [15].

2. Green GDP (GGDP). On the basis of referring to relevant literatures, this paper chooses green GDP as the measurement index of green economy development [16,17]. Green GDP is defined as:

$$\text{GGDP} = \text{GDP} - \text{Natural Resource Loss} - \text{Pollution Loss} \tag{1}$$

Where pollution loss = three wastes treatment cost + pollution direct economic loss.

The data of green GDP and green financial indicators are processed logarithmically in order to eliminate possible heteroscedasticity. Variable definitions are presented in Table 1.

Table 1. Variable definition table.

Variable name	Variable definition	Variable name	Variable definition
GGDP	Green GDP	Log (GGDP)	Green GDP after taking logarithm
INV	Investment of Environmental Protection Funds in China	Log (INV)	Investment of Environmental Protection Funds after taking logarithm

3.2 Constructing VAR Model

Christopher Sims proposed Vector Auto Regressive model (VAR model) in 1980. VAR model breaks through the limitation of causality and action direction between fixed variables in traditional economic model, and can effectively analyze the interaction among multiple variables [18]. Therefore, in order to explore the dynamic correlation between green economic growth and green finance, this paper constructs a VAR model. The VAR model constructed is shown in Eq. (2):

$$Y_t = C + \phi_1 Y_{t-1} + \phi_2 Y_{t-2} + \varepsilon_t \tag{2}$$

Where $Y = \begin{bmatrix} GGDP \\ INV \end{bmatrix}$, C represents 2×1 constant vector, ϕ_i(i = 1, 2) represents 2×2 Autoregressive Coefficient Matrix, ε_t represents 2×1 vector.

3.3 Data Sources

The time series data of green economy index and green finance index are selected from the annual data of China from 2004 to 2017. Data are collected from China Statistical Yearbook (2005–2018).

4 Empirical Analysis of the Dynamic Relationship Between Green Economy and Green Finance

4.1 Unit Root Test

For preventing the phenomenon of "pseudo-regression" in the two sets of time series data of Green Economy (GGDP) and Green Finance (INV), unit root test was carried out to determine that the two sets of time series data are stationary time series.

Eviews software was used to test the unit root of GGDP and Log (GGDP). We present the test results in Table 2. GGDP is a non-stationary time series and Log (GGDP) is a stationary time series.

Table 2. The unit root test results of GGDP and Log (GGDP).

GGDP		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		−0.116547	0.9187
Test critical values:	1% level	−4.420595	
	5% level	−3.259808	
	10% level	−2.771129	
Log (GGDP)		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		−3.684851	0.0357
Test critical values:	1% level	−4.803492	
	5% level	−3.403313	
	10% level	−2.841819	

*MacKinnon (1996) one-sided p-values

The unit root test of INV and Log (INV) was performed by Eviews. The test results as shown in Table 3 can be obtained as follows: INV is a non-stationary time series and Log (INV) is a stationary time series.

4.2 VAR Model Estimation Results

Eviews 8.0 is used to estimate the VAR model. The estimated results are presented in Table 4. As we can see: $R^2 = 0.992423$, and $\overline{R}^2 = 0.984847$, which shows that the established VAR model is very effective. The first and second lag stages of Log (GGDP) have a positive influence on Log (INV), and the first and second lag stages of Log (INV) also have significant positive effects on Log (GGDP).

4.3 Pulse Response Analysis Based on VAR Model

4.3.1 Stability Test of VAR Model

Referring to the previous stability test of VAR model, this study uses AR root to verify the stability of VAR model. According to the meaning of AR root test proposed in the

Table 3. INV and Log (INV) unit root test results.

INV		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		0.001758	0.9306
Test critical values:	1% level	−4.582648	
	5% level	−3.320969	
	10% level	−2.801384	
Log (INV)		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		−3.917012	0.0272
Test critical values:	1% level	−4.803492	
	5% level	−3.403313	
	10% level	−2.841819	

*MacKinnon (1996) one-sided p-values

Table 4. Estimated results of VAR model.

	LOG (GGDP)	LOG (INV)
LOG (GGDP(-1))	0.688183	1.169054
	(0.52431)	(0.73007)
	[2.31255]	[1.69929]
LOG (GGDP(-2))	0.149816	2.380886
	(0.47314)	(0.65881)
	[0.31664]	[3.61391]
LOG (INV(-1))	0.113643	0.040907
	(0.17201)	(0.23952)
	[2.66066]	[2.17079]
LOG (INV(-2))	0.033802	0.099681
	(0.16276)	(0.22663)
	[2.20768]	[0.43984]
C	0.918681	−4.589766
	(1.00471)	(1.39900)
	[0.91437]	[−3.28075]
R-squared	0.992423	0.988187
Adj. R-squared	0.984847	0.976373
Sum sq. Resids	0.013869	0.026890

(*continued*)

Table 4. (*continued*)

	LOG (GGDP)	LOG (INV)
S.E. equation	0.058884	0.081991
F-statistic	130.9830	83.64956
Log likelihood	16.36848	13.38900
Akaike AIC	−2.526329	−1.864222
Schwarz SC	−2.416760	−1.754653
Mean dependent	8.395943	4.372907
S.D. dependent	0.478341	0.533416

Note: Each column in the table represents a regression equation in the corresponding VAR model. Each coefficient can be tested by t statistics for the significance level of a single coefficient. The first row of each column in the table represents the regression coefficient, the values in parentheses represent the standard error, and the brackets represent the t value.

existing literature, if the reciprocal of all the root modules of VAR model are less than 1, that is, all the root modules are in the unit circle, then the model is stable; if the reciprocal of all the root modules of VAR model are greater than 1, that is, all the root modules are outside the unit circle, then the model is unstable [18]. Figure 1 can be obtained by analyzing data with Eviews 8.0 software. As can be seen from Fig. 1, the reciprocal of the four root modules lies in the circle with radius 1. Therefore, the VAR model constructed in this study is stable. This shows that the two variables selected in this paper have long-term stability, and impulse response function can be further applied to these two variables.

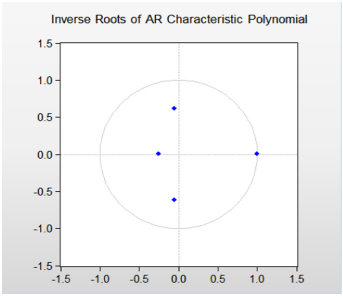

Fig. 1. AR root display of VAR model.

4.3.2 Impulse Response Analysis of Green Economy to Green Finance

The impulse response of green economy to green finance is shown in Fig. 2. If a standard deviation of the green financial indicators is given a positive impact, the green economic growth shows a fluctuating trend from top to bottom. When it reaches the second stage, the green economy growth reaches the maximum positive value, then gradually begins to decline and converge, and when it reaches the sixth stage, it begins to stabilize. This shows that green finance lags behind the growth of green economy. Green finance can drive the long-term growth of green economy. The positive effect is the greatest in the second period, and the driving effect will not gradually weaken with the increase of time. Generally speaking, increasing investment in green finance has a positive driving impact on green economy growth, that is, green finance supports the green economy.

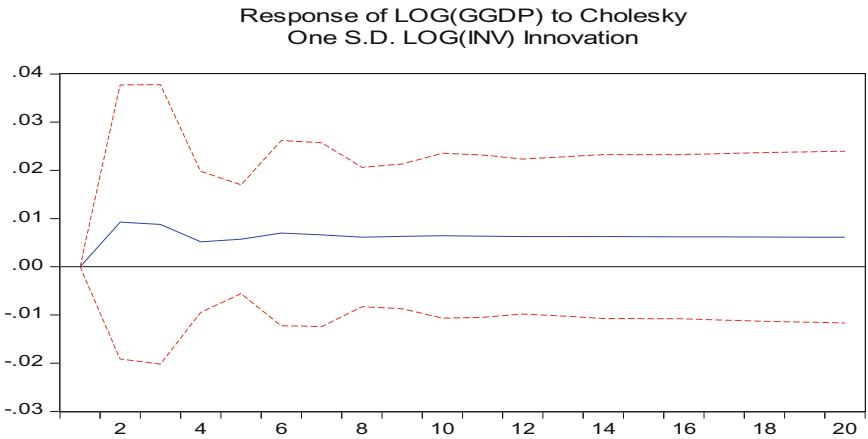

Fig. 2. Impulse response of Log (GGDP) to Log (INV).

4.3.3 Impulse Response Analysis of Green Finance to Green Economy

The impulse response of green finance to green economy is shown in Fig. 3. When a standard deviation is given to the green economy, green finance fluctuates from bottom to top, reaching the maximum negative response in stage 2, then fluctuates upward, reaching the maximum positive value in stage 3, and then converges gradually with the change of time. Finally, it tends to be stable in stage 10. This shows that in the first two stages, green economic growth has a negative influence on green finance, but with the passage of time, the impact of green economy on green finance begins to increase gradually. After reaching the positive peak, it begins to decline and tends to stabilize. Therefore, the impact of green economic growth on green finance changes greatly and lasts for a long time.

Generally speaking, the impulse response function analysis results manifest that increasing the input of green finance has a positive influence on green economy; and green economy also has a certain degree of impact on green finance, which will have a

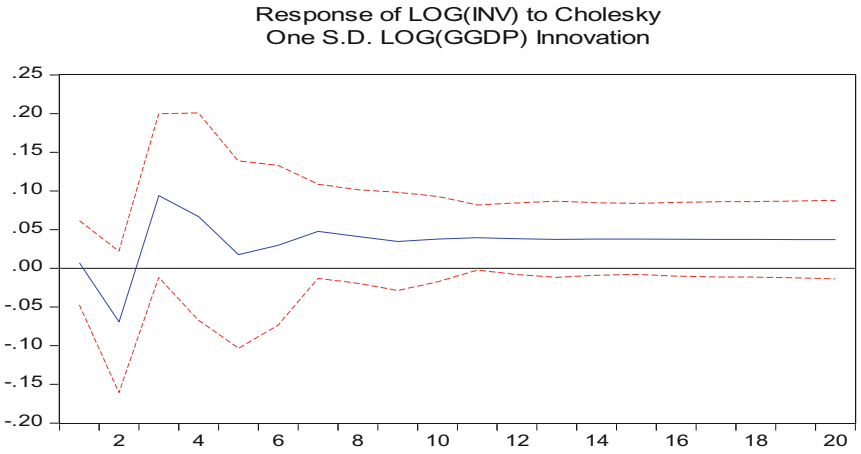

Fig. 3. Impulse response of Log (INV) to Log (GGDP).

negative impact in the early stage, but with the growth of time, green economy plays a positive role in promoting green finance.

4.4 Analysis of Variance Decomposition Based on VAR Model

Impulse response function describes the dynamic influence of one variable on another variable, and variance decomposition can decompose the variance of one variable into each perturbation term, so variance decomposition describes the relative impact level of each perturbation factor on each variable.

The variance decomposition of the green economy is shown in Table 5. From Table 5, we can see that in the contribution rate of green GDP, green GDP contributes the most to itself in the first stage, and shows a decreasing trend. In the sixth stage, it falls to 97.3%, and then shows a stable trend. This shows that the impact of green GDP on expectations decreases over time. However, the contribution rate of environmental protection investment to green GDP gradually increases with time, reaching 2.6% in the sixth stage, and then shows a steady trend. Therefore, the results of variance decomposition analysis show that the investment of environmental protection funds has a positive driving impact on green GDP, but the contribution rate of green GDP to itself is always far greater than the contribution rate of environmental protection funds to green GDP.

The variance decomposition of green finance is presented in Table 6. In the first stage, the contribution rate of environmental protection investment to itself is the greatest, and appears a decreasing trend. By the seventh stage, it falls to 96.9%, and then shows a stable trend. This shows that the impact of environmental protection funds on expectations decreases over time. However, the contribution rate of green GDP to the environmental protection investment increases gradually with time, reaching 3.0% in the seventh stage, and then shows a steady trend. Therefore, the results of variance decomposition analysis indicate that green GDP is positively driving environmental protection investment, but the contribution rate of environmental protection investment to itself is always far greater than the contribution rate of green GDP to environmental protection investment.

Table 5. Variance decomposition table of green economy.

Period	S.E	LOG (GGDP)	LOG (INV)
1	0.081991	100.0000	0.000000
2	0.107298	98.36272	1.637278
3	0.143879	97.37798	2.622015
4	0.159157	97.45830	2.541700
5	0.160949	97.54066	2.459335
6	0.163748	97.39960	2.600401
7	0.170621	97.30680	2.693196
8	0.175694	97.29287	2.707125
9	0.179284	97.27306	2.726942
10	0.183320	97.23863	2.761366

Table 6. The variance decomposition of green finance.

Period	S.E	LOG (INV)	LOG (GGDP)
1	0.0952	99.8621	0.1379
2	0.1184	98.0442	1.9558
3	0.1335	97.0594	2.9406
4	0.1488	97.1397	2.8603
5	0.1500	97.2221	2.7779
6	0.1534	97.0810	2.9190
7	0.1602	96.9882	3.0118
8	0.1653	96.9743	3.0257
9	0.1689	96.9545	3.0455
10	0.1730	96.9201	3.0799

5 Conclusion and Policy Recommendation

This paper chooses the annual data from 2004 to 2017 in China, uses VAR model, constructs impulse response function, and uses econometric analysis methods such as variance decomposition analysis to empirically analyze the dynamic link between green finance and green economy growth. The results make known that the first and second lag stages of Log (GGDP) have remarkable positive effects on Log (INV), and the first and second lag stages of Log (INV) also have prominent active effects on Log (GGDP). The results of impulse response function analysis show that green finance can promote

the growth of green economy; concurrently, the influence of green economy on green finance has gradually developed from the early inhibition to the promotion over time, showing a positive impact on the whole. From the results of variance decomposition analysis, green finance is positively influencing green economy, but the impact of green economy on itself is far greater than that of green finance. Green economy also actively promotes green finance, but the contribution rate of green finance to itself is always far greater than that of green economy.

Based on the empirical results obtained in this paper, for developing China's green economy and green finance, we put forward the following policy suggestions:

Firstly, increase green investment and realize green transformation. We should support the development of green economy with green finance. Therefore, increasing investment in green industry can alleviate some problems, which are caused by environmental pollution and destruction, and bring about sustained economic growth and green transformation development.

Secondly, we should improve tax policies conducive to green economy. There are few laws and regulations on green economy and green finance in China compared with western developed countries. The establishment and improvement of related policies are the foundation and guarantee for the development of green economy. Therefore, based on existing laws and regulations, government departments at all levels in our country can timely adjust the relevant fiscal policies, such as reducing the enterprise tax rate of environmental protection industry, green industry and other environmentally friendly industries, raising the tax rate of consumption-oriented enterprises, and giving some preferential policies to those enterprises that have successfully realized the green transformation.

Thirdly, develop new green financing channels. Vigorously publicize the importance of environmental protection, so that the main polluting enterprises in our country can enhance their awareness of environmental protection, and then provide these enterprises with green financing channels to deal with environmental pollution. China's financial institutions should develop other new financial instruments on the basis of existing financial instruments. We should increase investment in green credit and innovate financing channels for energy conservation, emission reduction and environmental pollution control technologies.

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