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Research Article

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Energy efficiency and investments in low-carbon economy: The impact of carbon finance on sustainability development

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ABSTRACT

In recent decades, the energy consumption growing faster with China's rapid economic grows. However, the energy efficiency in China is still at a low stage, so that how to improve the energy efficiency has become an important concern. Low-carbon economy requires changing the present situation of high energy consumption, and improving energy efficiency through the energy structure optimization and innovation. In this paper, we first construct an endogenous growth model and try to find out what is the main factor that effect on low-carbon economy growth. Then, using vector auto-regression model to test how financial development will effect on energy efficiency. The results prove that financial development can certain explain the improvement of energy efficiency, so that in the long run, financial development is the main factor to improve energy efficiency.

Key words: Low-carbon Economy; Energy Efficient; Carbon Finance; Vector auto regression (VAR) model

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INTRODUCTION

Fossil fuel consumption was increased significantly and resulting in environmental pollution and climate warming. This has seriously affected the ecological balance and human health. At present, China has put forward the strategic goal of improving energy efficiency. Low-carbon economy requires changing the present situation of high energy consumption, and improving energy efficiency through the energy structure optimization and innovation [1]. Previous studies showed that financial development will promote enterprise technological innovation and industrial upgrading; enterprises can increase the investment in R&D sector by financial support and this action will finally improve the production efficiency [2]. However, as China is an emerging country, this financial institution and financial service is not efficient, so that it still need research on the effectiveness of how the financial development will effect on China's low-carbon Economic Growth.

With the rapid economic growth in China, China has also facing a sharp energy consumption growth. China's total energy consumption equals as 3.62 billion tons of standard coal in 2012, increased by 3.9% from the previous year. Although in recent years China's energy efficiency has improved significantly, but China's energy efficiency is still at the low stage when compared with other developed countries[3-4]. Yuan pointed out that China's economic growth has a stable relationship with energy consumption. That means China is an energy-dependent economy and energy is a limiting factor to output growth in China [5]. By comparing China's annual energy consumption and economic growth data from 1990 to 2011, the result indicates that the energy consumption and economic growth have synchronous growth trend.

Osborne and Kiker(2005) pointed out that although developing countries adopted a variety of measures in climate change mitigation, but the decrease of energy production will effects the economic benefits, so the final solution will ultimately come from in improving energy efficiency[6]. Sarkar and Singh (2010) pointed that how to improving energy efficient is still a challenge in development countries. The result shows that financial instruments will proved

adequate liquidity and can be used for accelerating the process of low-carbon economy [7]. Carraro et al. (2012) pointed that carbon tax revenues are very high in developing countries, however, the investment in R&D still occupy a low share of GDP. Therefore, the government should make out effective taxation schemes, both to reduce greenhouse gas emissions and promote low-carbon technology innovation [8]. Chevallier (2011) used factor-augmented vector auto regression model to analyze how international economic shocks impacts on carbon markets, the result shows that carbon prices has obvious relationship with most global economic indicators[9].

Zou et al. (2011) pointed out that China government has began to strengthen efforts to propagate and support carbon finance, however, carbon finance is still faced with management problems and risks. So that commercial banks are required to improve their service level and develop new carbon trading products [10]. Zhang and Dan-dan (2012) pointed out China's low-carbon economy could be fulfilled through the technical innovation and efficient energy utilization [11]. There are also some researches about how technical innovation effects on energy efficiency [12-14]. Based on previous studies, it shows that the development of finance can promote enterprise technological innovation and industrial upgrading, enterprise through financial support can strengthen the investment to R&D department, and the enterprises can promote energy efficiency and reduce carbon emissions through technological innovation.

There are also many academic scholars research about carbon finance and low-Carbon strategy in China. Li and Colombier (2011) find that the current China's energy efficiency standard become to one of the best practices in the world, and with international support such as carbon finance, the energy efficiency improvement will facilitate city's transition to low-carbon supply in the longer term[15]. Zhou (2010) pointed out that carbon finance is related to all financial transaction activity that can reduce carbon emissions. The development of carbon finance can make contribute to economy transform and accelerate the optimization of economic structure [16]. Zhao and Zhang (2012) analyzed the internal and external factors which affect carbon finance in China, and put forward the reasonable path of how to develop carbon finance in China [17]. Also, Zhao and Zhang pointed out that China government should set up a full range of policies and regulations.

Sun and Zhu (2008) using panel data from 23 provinces in China and find out that the technology innovation level had been gradual increased in these areas with the financial development [18]. The empirical result shows that there had been a gradual growth in the TFP and technological progress from 2001 to 2005, which is tested by variant intercept model in panel data. Qian and Zhou 2011 analyzed the data of all 28 provinces in China from 2000-2008. By using the fixed effects panel data regression with AR(1) approach to estimate the TFP and the level of financial development in all regions, the result indicates that after controlling the other relevant variables, financial development also plays a positive role in technological progress and industrial upgrading[19].

To sum up, financial development can promote technology innovation and improve energy efficiency; at the same time, through the continuous improvement of the carbon financial market system in China, China's carbon emissions will reduce further [20]. Based on the discussion above, this study first construct an endogenous growth model and try to find out what is the main factor that effect on low-carbon economy growth. Then, using vector auto-regression model to make an empirical analysis about how financial development will effect on energy efficiency. The structure of this study is as follows: the first part is the literature review, the second part is modeling construct and analysis, the third part is empirical analysis based on vector auto-regression model and the fourth part is the conclusion based on empirical result.

EXPERIMENTAL SECTION

2.1 Data collection and processing

Using financial intervnational ratio to represent the financial development level and using energy efficiency index to represent the level of Low-carbon economy. The formula of financial intervnational ratio is M2/GDP and the formula of energy efficiency index equals GDP/ (energy consumption). The data was then undertook log processing, noted as LnFIR and LnEE. All data was collected from "China statistical yearbook 2012". By comparing China's annual energy consumption and economic growth data from 1995 to 2011, the result indicates that the energy consumption and economic growth have synchronous growth trend, as shown in figure 1.In figure 1, primary Y-axis (left side) indicates China's gross domestic product (GDP), the unit is one hundred million RMB; secondary X-axis (right side) indicates energy consumption, the unit is ten thousand tons of standard coal. From figure 1, it shows that the rapid growth of China's gross domestic product (GDP) is based on increased energy consumption. From year 2002 China's GDP began to rapid growth, while energy consumption has started to increase sharply. Meanwhile, China's current energy efficiency is low; the economic growth mainly depends on the energy consumption, so that the extensive economic growth mode is still the main development pattern.

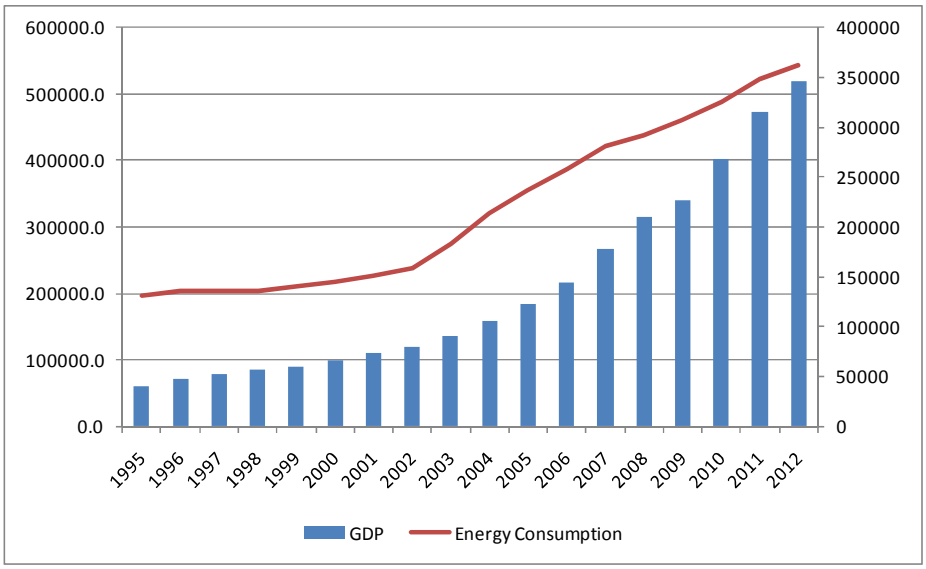


Figure 1. Trend of GDP and energy consumption during 1995–2012 in China

2.2 ADF unit root test

In statistics and econometrics, an augmented Dickey–Fuller test (ADF) is a test for a unit root in a time series sample. By using augmented Dickey-Fuller unit root tests, the result as is shown in table 1. Through the test results in table 1, it shows that LnFIR and LnEE are non-stationary at 10% critical value. However, after differential calculation d.LnFER and d.LnCPI are stable, so that VAR model can be used to analyze the data.

Table 1: Data stationarity test through augmented Dickey–Fuller analysis

variable	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value	result
LnEE	0.301	-3.750	-3.000	-2.630	unstable
LnFIR	-1.383	-3.750	-3.000	-2.630	unstable
D.LnEE	-3.599	-3.750	-3.000	-2.630	stable
D.LnFIR	-3.655	-3.750	-3.000	-2.630	stable

Table 2: The result of optimal lag-order selection for VARs

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	15.2675				.000785	1.47416	1.46052	1.37523
1	68.1441	105.75	4	0.000	3.5e-06	-6.90489	-6.86397	-6.6081
2	77.4148	18.542*	4	0.001	2.0e-06*	-7.49054*	-7.42233*	-6.99588*
3	79.9482	5.0667	4	0.281	2.5e-06	-7.32758	-7.23209	-6.63507
4	81.5312	3.166	4	0.530	3.6e-06	-7.05902	-6.93625	-6.16865

**Means that lag 2 is the optimal lag order.*

2.3 VAR model

Vector auto regression (VAR) model is the simultaneous form of autoregressive model, A VAR (p) model of a time series y (t) has the form:

$$A_0 y_{(t)} = A_1 y_{(t-1)} + \cdots + A_p y_{(t-p)} + \varepsilon_{(t)}$$

According to the analysis above, the VAR regression model of LnFIR and LnEE can be constructed. Before constructing the VAR model, the lag of VAR Model should be determined. By using STATA software to calculate the lag length, the result was shown in table 2. From the table 2, the result shows that the optimal lag length is at lag 2. By choosing lag 2, then the VAR model can be shown as:

$$\begin{aligned} LnEE = & -0.197 + 0.568 LnFIR_{t-1} + 0.198 LnFIR_{t-2} \\ & + 1.807 LnEE_{t-1} - 0.989 LnEE_{t-2} \end{aligned}$$

According to this formula, it shows that the financial development will promote energy efficiency index increase. LnFIR at lag 1 period increased one percentage will lead LnEE increased by 0.56 percentage points, and LnFIR at lag 2 period increased one percentage will lead LnEE increased by 0.19 percentage points. So the effect of financial

development to energy efficiency is obvious. Then, by using granger causality test to analyze the relations between LnFIR and LnEE, the result is shown in table 3.

Table 3: Causal relationship test through Granger causality analysis

Equation	Excluded	chi2	df	Prob > chi2
LnEE	LnFIR	8.3984	2	0.015
LnFIR	LnEE	10.423	2	0.305

Table 4: Long-term equilibrium relationship test through Johnson Co-integration analysis

Rank	Parms	LL	Characteristic Value	Statistic	5% Significant level
0	N/A	13.5214*	15.41	0	N/A
1	0.45382	2.0299	3.76	1	0.45382

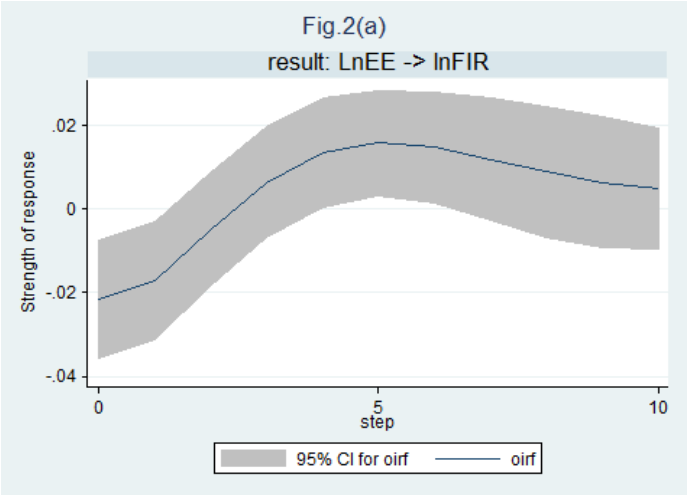
From Table 3, the result shows that LnEE rejected the null hypothesis as"Excluded LnFIR as the granger reason to LnEE", so that LnFIR is the granger reason to LnEE, which means financial development is the reason promotes energy efficiency index increase. However, it shows that LnEE is not the reason for LnFIR. At the same time, by taking Johnson co-integration test to analyze the long-term relations between LnFIR and LnEE, the result is shown in table 4.From table 4, the result shows that there exist at least one direct co-integration relationship between LnFIR and LnEE, which means that there exists a long-term equilibrium relationship between financial development and energy efficiency.

2.4 Impulse-response analysis and variance decomposition

Impulse-response function and cholesky variance decomposition can be used to further analyze the VAR model. An impulse response refers to the reaction of any dynamic system in response to some external change.

The result of Impulse-response analysis was shown in figure 2. In figure 2, X-axis indicates the time period, and Y-axis indicates the strength of response. From Fig.2(a), the result shows that when LnFIR received one unit impact, it will lead LnEE increase currently, LnEE will reach the max at t=5 period and then begin to stable. It illustrates there is long-term effect between financial development and energy efficiency increase. From Fig.2(b), the result shows that when LnEE received one unit impact, it will lead LnEE increase currently. However, LnEE will reduce to 0 at =5 period, which means the impulse of LnEE only has short-term effects to itself. ccording to the impulse analysis results, it shows that financial development will significant influence energy efficiency.

The variance decomposition indicates the amount of information each variable contributes to the other variables in the auto regression. It determines how much of the forecast error variance of each of the variables can be explained by exogenous shocks to the other variables. The result of variance decomposition was shown in figure 3. From Fig.3(a), the result shows that the contribution degree of LnFIR to LnEE is gradually increased, the contribution degree of LnFIR to LnEE is about 30%-40% in the all time period, which means LnFIR has strong a degree of contribution to LnEE. From Fig.3(b), the result shows that the contribution degree of LnEE to LnEE is gradually reduced, the contribution degree of LnEE to LnEE is 100% at t=1 period and reduced to 40% at t=10 period. This shows that financial development has significant effect on the energy efficiency, and can explain the improving the energy efficiency.



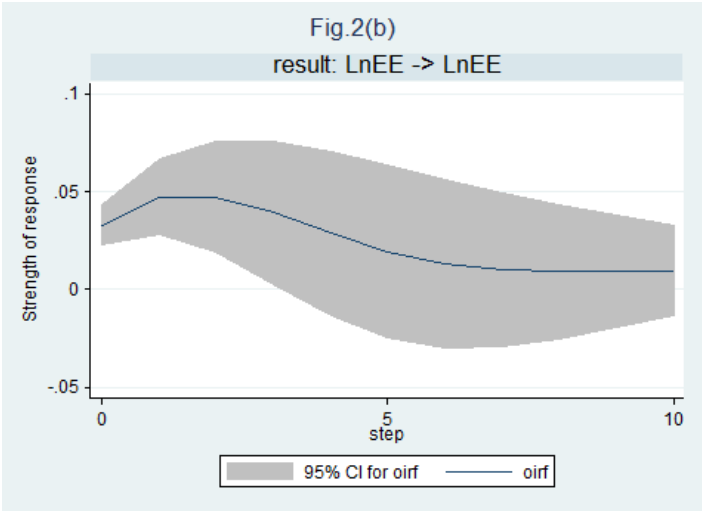
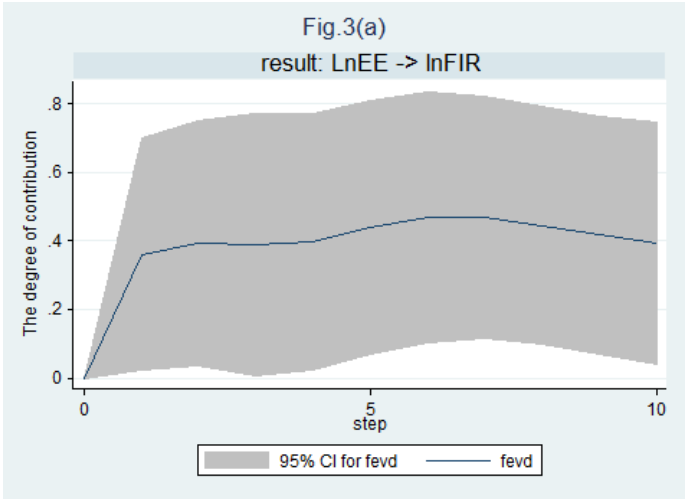


Fig. 2(a-b): Result of impulse-response analysis for(a)the response of LnEE when LnFIR received one unit impact, (b) the response of LnEE when LnEE received one unit impact

To sum up, by constructing the endogenous model, it proved that technological innovation is the main reason to achieve low-carbon economic growth.The result of empirical study shows that financial development is the granger reason to the improving of energy efficient. Once financial development received one unit impact, it will lead energy efficient increase currently. The result is same to the research from Sarkar and Singh (2010) which proved financial development will accelerate the process of low-carbon economy. However, the empirical study in section 3 did not test whether financial development will effect on technological innovation, it didn't prove that financial development first improve R&D and then the improving of R&D effects on energy efficient. According to the literature from Sun and Zhu (2008); Qian and Zhou (2011), it shows that financial development in China will promote technological innovation. At the same time, technological innovation will finally effects on the improving of energy efficient. So that, it can be proved that financial development will accelerate the process of China's low-carbon economy.



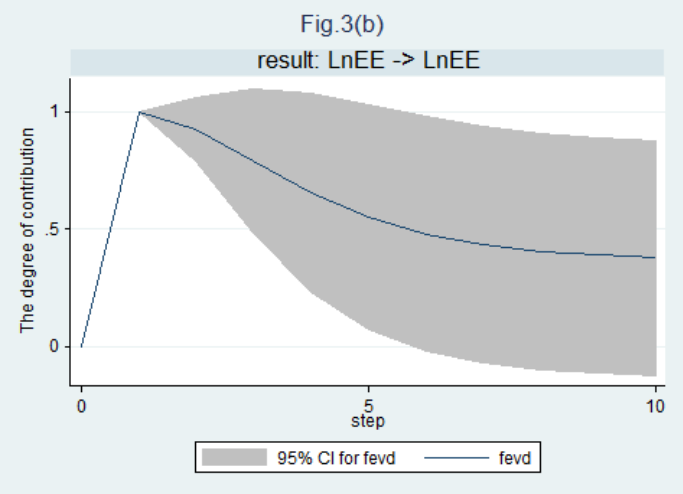


Fig. 3(a-b): Result of Cholesky variance decomposition for (a) contribution degree of LnFIR to LnEE, (b) contribution degree of LnEE to LnEE

DISCUSSION

In order to improve the effectiveness of low carbon development strategy, the government should put forward effective policies. First of all, in the process of low carbon economy development strategy, the government should play the leading role. Government should give more support and provide a good policy environment by establishing and improving the relevant policies and regulations. Also the government should establish the China's carbon finance system and promote the innovation of carbon financial products. At the same time, the Chinese government should ensure the implementation of low-carbon economy strategy by using tax and subsidy policies. Second, commercial banks should increase financial products and services to low-carbon industry. Because of the money demand for low-carbon projects is very large, commercial banks should develop new loan products provide carbon financial services, so that commercial banks can provide the necessary financial support to the Low-carbon innovation in enterprises.

However, this research still has some drawbacks. First, the empirical analysis did not test the promotion function of financial development for technical innovation; also the measure of financial development can be more comprehensive. Second, as China’s energy consumption has obvious regional differences, so that the impact of financial development on energy efficient will be difference in different areas. These problems still need further research.

CONCLUSION

In conclusions, the result of VAR model shows that financial development is the Grainger reason to energy efficiency. According to the VAR model, it shows that the financial development will promote energy efficiency index increase. Financial development index at lag 1 period increased 1 percentage will lead energy efficient increased by 0.56 percentage points, and financial development index at lag 2 period increased 1 percentage will lead energy efficient increased by 0.19 percentage points. At the same time; the result of Johnson Co-integration analysis shows that here exists a long-term equilibrium relationship between financial development and energy efficiency. From the variance decomposition results, the result shows that the contribution degree of financial development to energy efficient is gradually increased; also the contribution degree of financial development to energy efficient is about 30%-40% in the all time period, which means financial development has strong a degree of contribution to energy efficient. The results prove that financial development can certain explain the improvement of energy efficiency, so that in the long run, financial development is the main factor to improve energy efficiency. In recent decades, the demand of energy fuel was increased dramatically with China's rapid economic growth, as the financial industry could be an important support to the low-carbon economy, so the government should strengthen the financial factor as reform of the financial system, provides the corresponding policy support for China's carbon finance market and promote innovation of carbon financial products.

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