Economic Horizons, May - August 2014, Volume 16, Number 2, 81 - 96
UDC: 33 eISSN 2217-9232

Original scientific paper
UDC: 330.354:330.322(510) ; 330.322:621.311
doi: 10.5937/ekonhor1402085Y

ELECTRICITY INVESTMENT AND ECONOMIC GROWTH IN CHINA: A DEMONSTRATION AND A FORECAST BASED ON THE VAR MODEL

Fan Yuxian*, Yuan Xiaoling, He Songke

School of Economics and Finance of Xi 'an Jiaotong University, Xi 'an, Shaanxi, China

This paper represents a study on the dynamic influence of electricity investment on economic growth, which is based on the data from 1953 to 2012, by using the ADF test, the Granger test, the VAR model, the IRF (Impulse Response Function) model and the VEC model. In this research, other factors such as more fixed-asset investment and labor force are involved in the explanatory variables. The results are used to forecast the scenarios of economic growth on different electricity investment projects. The results indicated that electricity investment can strengthen economic growth in a short time when there is a steady equilibrium relationship in the long run. The positive impulse response of economic growth to electricity investment will last for four years. The contribution of electricity investment to economic development has been increasing year by year. The scenario analysis means that an S-shaped electricity investment is better than other investment projects in the promotion of economic growth.

Keywords: electricity investment, economic growth, VAR model, scenario forecast

JEL Classification: O18

INTRODUCTION

In the 21st century, in response to energy security, climate change, the financial crisis and many other issues, European and American countries respect developing a smart grid as an important measure to deal with these crises, and it is considered within the national economic development and energy policy frameworks and is gradually put up to the national strategic level. In China, the construction of the UHV (ultra-high voltage) power grid started in 2006. The Outline of the Twelfth Five-Year Plan for Chinese National and Development Strategies (http://www.gov.cn/2011lh/content_1825838.htm) clearly put forward to develop a UHV power grid and to advance a smart grid construction, marking the construction of a smart grid into the national development strategies. Investing in a smart grid not only involves the transmission, transformation, distribution and use of the power industry but also forms a huge stimulus on upstream electrical equipment, electronic information, new materials, electric vehicles and other industries. According to the smart grid development plan, China's electricity industry investments are about 6.1 trillion yuan during the Twelfth Five-Year Period and about 7.1

**Correspondence to:* F. Yuxian, School of Economics and Finance of Xi 'an Jiaotong University, West Road 74 of Yanta, Xi'an, Shaanxi, China; e-mail: qdfyx2002@stu.xjtu.edu.cn

trillion yuan in the Thirteenth Five-Year Period. What impact did the smart grid investment have on China's economic growth in the end? This is an obvious question worth exploring. In this paper, we start from the hypothesis that electricity investment is important for economic growth.

A REVIEW OF THE LITERATURE

The majority of the studies in the existing literature on power and economic growth are concentrated on electricity consumption and economic growth. For example, JIANG Jin-he and YAO Yu-fang (2002), ZHANG Lin , HE Lian-chen and WANG Jun-xia (2008), LI Qiang, WANG Hong-chuan and HU An-gang (2013) and P Zhou, BW.Ang and K L Poh. A (2006) etc. examine the relationship between economic growth and China's power consumption from different perspectives. QU Xiao-yan, ZHANG Shi-tong and WU Yan-yan (2011) uses the input-output model to analyze the pulling effect of coal, oil, electricity and other industries on the national economy. However, studies on the relationship between electricity investment and economic growth are rare and the relevant content is only scattered in researches on the relationship between infrastructure investment and economic growth.

Research on the relationship between infrastructure investment and economic growth consists of theoretical and empirical research. A. Smith (2000) puts forward that „building and maintaining certain public utilities and certain public facilities (i.e. the infrastructure) are one of the main functions of the government". His famous division of labor theory emphasizes that the level of the division of labor is determined by the size of the market, and the market size and the development degree of commercial are determined by the public infrastructure level. These budding ideas have noted the important role of infrastructure on national wealth. D. Greenwald (1982) points out that the infrastructure „directly or indirectly helps to improve the level of the output and productivity of economic activities, including transportation, power production, telecommunications and banking, education and sanitation systems, and the orderly government and political structure is an important guarantee for the infrastructure". There are four perspectives on the relationship between the infrastructure and economic growth: First, the use of the Keynesian multiplier theory and the effective demand ideology proves that infrastructure investment into a national economy as a factor leads to a direct increase in the total output and promotes the accumulation of capital through the multiplier effect. In the 1940s, development economists considered infrastructure investment bringing capital accumulation as a prerequisite for economic development. Second, the neoclassical growth theory represented by R. Solow (according to: N. G. Mankiw, 2006) in accordance with „the law of diminishing marginal returns" concluded that infrastructure investment only has short-term effects on economic growth and that long-term economic growth is not dependent on infrastructure investment, but rather on exogenous technological progress. Third, the endogenous growth theory represented by R. J. Barro (2007) considers that an investment in the infrastructure characterized by congestion can improve long-term economic growth. Fourth, the new classical economics considers that infrastructure investment by reducing transaction costs improves transaction efficiency and promotes economic growth. As you can see from the above theoretical review, there are still differences in whether infrastructure investment can promote economic growth and a degree of an impact on economic growth and other issues. In recent years, the development and maturity of the econometric theory and methods have been providing an effective analysis tool for economists to examine the relationship between infrastructure investment and economic growth.

Domestic and foreign scholars have carried out a large number of empirical studies on the relationship between infrastructure investment and economic growth. Feng-Cheng Fu, Chu-Ping C. Vijverberg and Wim P. Vijverberg (2004) considers infrastructure investment to have a significant impact on labor productivity in the region, although it cannot promote long-term economic growth. S. T. Chen, H. I. Kuo, and C. C. Chen (2007) believes that electric power, communications and transportation infrastructure investment has a stimulating effect on economic growth and economic growth will generate greater demand on the infrastructure. LIU Lun-wu (2005) establishes the error correction model to study the role of the infrastructure in promoting economic growth in China and its eastern, central and western regions, and thinks that infrastructure investment can greatly stimulate economic growth. Using the spatial panel econometrics method, LIU Bing-lian, WU Peng and LIU Yu-hai (2010) concludes that the Chinese transportation infrastructure significantly promotes the growth of the total factor productivity. Based on the VAR (Vector Auto-Regression) model, REN Rong, CHENG Lianyuan, XIE Zhuoran and ZONG Gang (2012) study the dynamic relationship between the transportation infrastructure investment and economic growth, and think that the transportation infrastructure contributes to economic growth, and that it is persistent and increases every year. PENG Yu (2012) considers that the main reason for the promotion of electricity investment in economic growth is that the local government lacks the enthusiasm of environmental protection. M. Khanna and N. D. Rao (2009) examine the relationship between electricity consumption and economic growth.

Despite the fact that many scholars have studied the relationship between infrastructure and economic growth from the theoretical and empirical angles in depth, the range of infrastructure is wide and the promotion effect and the degree from diverse infrastructure on the development of an economy are different. At present, there are few scholars who study the effects of the electricity infrastructure investment on economic growth, but in the new situation of the current global economic downturn, developed countries take electricity investment as an important breakthrough to promote economic growth and energy security; so it is necessary to study the relationship between electricity investment and economic development specially and in depth.

Compared with the previous research, the difference of this paper lies in the following:

1. Regarding the research content and the research scope, the previous specialized researches on the relationship between electricity investment and economic growth are rare and related researches are only scattered in the literature on infrastructure investment, while this paper studies the relationship between the electricity investment and economic growth based on an empirical analysis of the VAR model. The study selects large sample data from 1953 to 2012, which makes up for the defects of the inaccuracy of the experimental results of the VAR model due to the lack of sufficient samples in the previous research.
2. Regarding the research ideas, the long-term and short-term equilibrium relationship between the variables are tested by applying the VAR models, and by using the empirical results, the forecasts and the comparison of different projects on the impact of electricity investment on economic growth are made under different investment scenario modes from 2013 to 2020.

MODEL CONSTRUCTION AND VARIABLE DEFINITION

Theoretical Models

Assuming the Cobb–Douglas (C-D) production technology, the output (Y) is determined by two types of the factors of production inputs, which factors are the labor force (L) and the capital (K), as it is shown in Equation 1:

$$Y = AK^{\alpha} L^{\beta} e^{\theta t + \upsilon} \tag{1}$$

wherein, A is a constant; e is the error term; t is time, which are Hicks-neutral technical parameters; v is a random white noise, as the elasticity of the two inputs of α and β. The model can be extended, and the other factors that may affect the output can be added in the C-D production function. In this paper, in order to study the relationship between electricity investment and economic growth, investments will be decomposed into electricity investment in fixed assets and other fixed-assets investment, and the Cobb-Douglas production function is modified as follows:

$$GDP = AD^{\alpha} T^{\beta} L^{\gamma} e^{\theta t + \upsilon} \tag{2}$$

where GDP, D, T, L denote the output, electricity investment in fixed assets, other fixed-assets investment and labor, and α, β and γ are the corresponding input elasticity. The output is represented by the gross domestic product – GDP. It can be obtained from the C-D function above:

$$\ln GDP = \alpha_0 + \alpha_1 LND + \alpha_2 LNT + \alpha_3 LNL + \mu_{it} \quad (3)$$

Data Explanation

It should be noted that, due to the incomplete data of electricity investment in fixed assets in the yearbooks, the data about the investment in the fixed assets of the „electricity, gas, water production and supply industries" are used in this paper to represent it. According to the comparison of some years, the electricity investment accounts for more than 70% in the investment of this industry, so taking this data as the representative of the electricity investment is reliable and the analysis does not affect the measurement results and conclusions. In addition, another investment is obtained after deducting the electricity investment from the whole social investment in fixed assets. The data in this paper is from the *Chinese Statistical Yearbook, China's Population and Employment Statistics Yearbook, New Chinese Sixty-Year Statistical Data Collection* and Chinese information website. In order to eliminate the effects of the inflation and other price factors, the annual GDP and investment data will be translated into the actual price according to the residents' consumer price index, which was 100 in 2005. At the same time, in order to eliminate the heteroscedasticity arising from time series, a logarithm of the above data is used.

ELECTRICITY INVESTMENT AND ECONOMIC GROWTH - AN EMPIRICAL ANALYSIS BASED ON HISTORICAL DATA

The current situation of China's electricity investment

On the overall scale of investment, China's electricity investment has increased year by year since 1980s. Since the beginning of the twenty-first century, intelligent power upgrading has especially been promoting the rapid growth of investment in electricity. Calculated at comparable prices, the scale of electricity investment in 2012 is 85 times of the one in 1980. The proportion of electricity investment accounting for the GDP shows an overall upward trend, especially since the construction of intelligent power, and the share of electricity investment accounting for the GDP increased from 1.73% in 2002 to 4.23% in 2009, indicating that the role of electricity investment in the national economy enhanced (Figure 1).

As seen in Figure 2, electricity investment and economic growth have almost the same growth trend, which indicates that electricity investment is likely to have a significant impact on economic growth, and there is an important correlation between them. Further empirical tests are needed to confirm this speculation in the following manner.

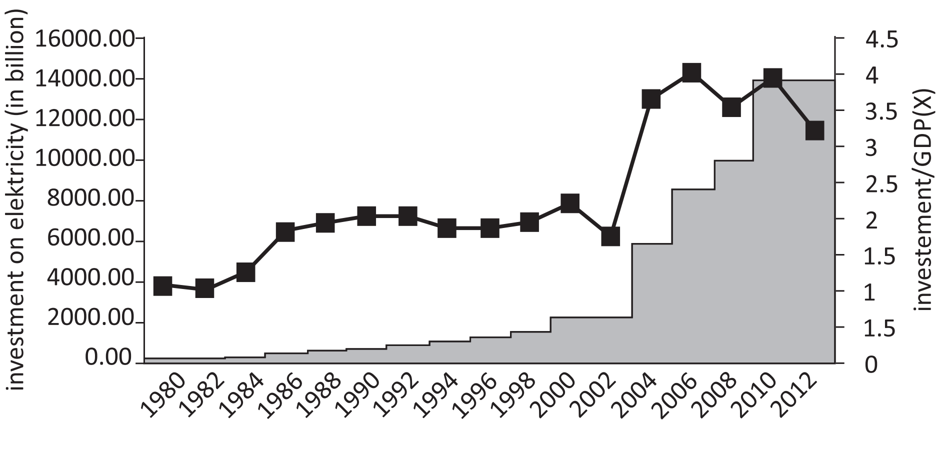

Figure 1 Scale of eletricity investment and ratio

Source: Authors, based on: *Chinese Statistical Yearbook*

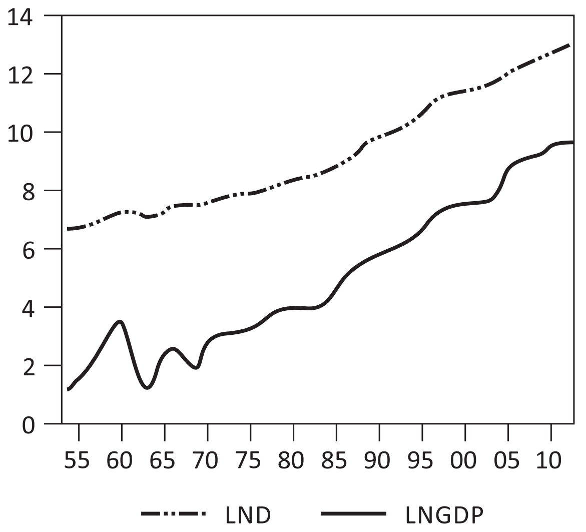

Figure 2 The trends of China's electricity investment and economic growth from 1953 to 2012

Source: Authors, based on: *Chinese Statistical Yearbook*

The co-integration analysis of electricity investment and economic growth in China

The ADF unit root test

To analyze whether there is a long-term stable equilibrium relationship between the variables and economic growth, a stationary test is done for the time-series variables first. By using the eviews6.0 software, stationary tests on LNGDP, LNK, LND and LNL sequences are done, and the results are shown in Table 1. The values of the ADF test of the original sequence show that it cannot reject the null hypothesis that there is a unit root, which indicates that LNGDP, LNT, LND and LNL are non-stationary time series. After the first-order difference, the four-time series have become stationary sequences, and they are single integer sequences which can be used to perform a co-integration analysis.

The co-integration test

Before the co-integration test, AIC and SC criteria are used to test and determine the optimum lags. From Table 2, the VAR model lag order cannot be determined by this method because the minimum values of SC and AIC correspond to different P values. Using the log likelihood ratio statistic LR to select the P value, and the null hypothesis is that the lag is 1, it is possible to obtain the likelihood ratio statistics LR = - 2 · (306.0489 - 321.2630) = 30.4282,
the freedom degree being 16, and the probability P = 0.0159 < 0.05 obtained by the eviews6.0 software, so the null hypothesis can be rejected, and the optimal lag order is 2; at the same time, the (VAR2) model will be established in the following analysis.

Table 1 The ADF unit root test of series

Variables	ADF Statistics	Test Type*	Critical value	DW value	Conclusion
LNGDP	-1.071972	(c,t,3)	-3.492149	1.986158	Non-stationary
⊿LNGDP	-5.776781	(c,0,1)	-2.913549	2.162402	Stationary
LNT	-1.603520	(c,t,3)	-3.492149	1.931405	Non-stationary
⊿LNT	-6.172521	(c,0,1)	-2.913549	2.144704	Stationary
LND	0.453879	(c,0,3)	-2.914517	2.021891	Non-stationary
⊿LND	-6.125442	(c,0,2)	-2.914517*	2.011789	Stationary
LNL	0.073085	(c,t,0)	-3.487845	1.862737	Non-stationary
⊿LNL	-6.445394	(c,0,0)	-2.912631	2.019803	Stationary

*Note: The c, t, k in test types, respectively, denote the constant term and the trend items and the lag order. The minimum SIC value is the criterion of the lag order. The significance level of the critical value is 5%.

Source: Authors

Table 2 Changes of the AIC and SC values with the P

P	AIC	SC	Lnl (p)*
1	-9.696573	-8.992323	306.0489
2	-9.836654	-8.557758	321.2630
3	-9.725371	-7.861534	329.1731
4	-9.672251	-7.212895	338.8230

*Note: Lnl (p) means the corresponding values of the log-likelihood.

Source: Authors

According to the principle of econometrics, if two or more time series variables are non-stationary while their linear combination is stationary, the variables are co-integrated and there is a long-term stable equilibrium relationship between them. As it involves the multiple variables of LNGDP, LND, LNK and LNL in the co-integration relationship, the Johansen Co-integration Test is used, which test Johansen (1991) used to estimate the long-run equilibrium relationship of the model based on the dynamic distributed lag model (VAR), making up for the deficiency of the parameters estimation of the EG two-step method in a small sample. As the optimal lag of the VAR model obtained by the LR test is 2, we select the lag (11) in the co-integration test. As to intercept and trend items, forecasts are made from simple graphics according to the nature of the series, and they are selected after many comparisons between the estimation and the basic economic principles. The results of the co-integration test are presented in Table 3.

Table 3 The results of the Co-integration Test

Number of Co-integrating Vectors	Eigenvalues	Trace Statistic	Significance Level of 0.05	P Value
None	0.336212	49.06587	47.85613	0.0383
At most 1	0.203127	25.29793	29.79707	0.1511
At most 2	0.162490	12.12848	15.49471	0.1509
At most 3	0.031290	1.843790	3.841466	0.1745

Source: Authors

The trace test results show that the null hypothesis of the non-existence of co-integration is rejected at a significance level of 5%; when the rank number is 1, the trace statistic is less than the critical value of the 5% significance level, and the P value is greater than 0.05, so the null hypothesis of the existence of one co-integrating relationship is accepted. There is only one co-integration relationship between the four variables, which can reflect the long-term stable equilibrium relationship between the variables; the standard co-integration equation is displayed in the following manner:

$$\ln GDP = 0.717\,LnD + 0.0245\,LnT + 0.3305\,LnL \quad (4)$$
$$(0.23808) \qquad (0.26735) \qquad (0.34258)$$

The estimate of the standard deviation is in the brackets of the model, and because of the original numerical logarithm, the value of the estimated coefficient indicates elasticity. The electricity investment, other investment and labor-force investment elasticity of economic growth is respectively 0.717, 0.0245 and -0.3305, indicating that the GDP growth increases 0.717% with the electric power industry's investment increasing 1%; the GDP growth increases 0.0245% with the other investment increasing 1%; and the negative growth of the GDP comes with employment growth. The main reason for negative employment elasticity may be that modern economic growth increasingly depends on technology innovation, increasing investment and promoting production efficiency and other factors, which will save a lot of labor. The positive effect of electricity investment on economic growth verifies the intuitive judgments of the relationship between the two in Figure 2.

The Vector Autoregressive Model of relationship between electricity investment and economic growth

The Vector Autoregressive Model

The time series model is suitable for the forecasting of relevant time series and a dynamic impact on the variables system from random perturbations, and according to the LR test results, the VAR (2) model is established. Using the AR characteristic roots to test VAR models, all the absolute values of the unit roots fall within the unit circle (Figure 3), indicating that the structure of the VAR model is stable.

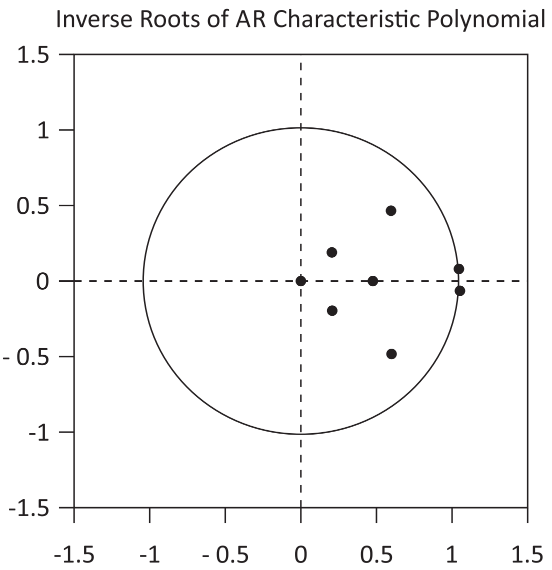

Figure 3 Tests on the stability of the VAR model lag structure

Source: Authors

The estimation results of the VAR (2) model are accounted for in the equation (5). The impact parameter of the lagging one period of the LNGDP to itself is 1.814, which is statistically significant (the t-statistic of 6.548), and the impact of the lagging two periods of itself is negative and statistically not significant (the t-statistic of -1,896); the effects of the lagging one period of the LNT to the LNGDP is negative, while the lagging two is positive, but the impact parameters are relatively small and the corresponding t-statistic is not significant; the impact of the lagging one period of the LND to the LNGDP is positive and the lagging two is negative. The results above show that changes in the GDP can significantly affect changes in the same direction in the next stage, and that electricity investment has a positive impact on the GDP in the next period, while other investments do not obviously impact the gross domestic product of the next two periods.

The Granger Causality Test of the VAR Model

The results of the co-integration test only show that there is a long-term equilibrium relationship between the variables, and whether a causal relationship between the variables exists, namely whether the relationship of the variables is exactly true causal links or just a data coincidence, needs to further be verified by a Granger analysis. The test results in Table 4 show that there is a two-way Granger causality relationship between other investment and economic growth, while there is only a unidirectional causality relationship by the electricity investment to the economic growth between them, and there is a two-way Granger causality relationship between labor investment and economic growth, and the relationship between the remaining variables can similarly be explained.

$$\begin{pmatrix} LnGDP \\ Lnt \\ LnD \\ LnL \end{pmatrix} = \begin{pmatrix} -1.386 \\ -2.493 \\ -5.264 \\ -0.252 \end{pmatrix} + \begin{pmatrix} 1.814 & -0.288 & 0.046 & 0.302 \\ 2.597 & 0.011 & 0.234 & 0.774 \\ 1.545 & -0.475 & 1.126 & 1.229 \\ -0.015 & -0.060 & 0.033 & 1.034 \end{pmatrix} \begin{pmatrix} LnGDP\ (-1) \\ Lnt\ (-1) \\ LnD\ (-1) \\ LnL\ (-1) \end{pmatrix} +$$

$$\begin{pmatrix} -0.559 & 1.133 & -0.079 & -0.268 \\ -1.727 & 0.333 & -0.208 & -0.853 \\ -0.688 & 0.283 & -0.560 & -1.157 \\ 0.028 & 0.0560 & -0.047 & -0.010 \end{pmatrix} \begin{pmatrix} LnGDP\ (-2) \\ Lnt\ (-2) \\ LnD\ (-2) \\ LnL\ (-2) \end{pmatrix} + \begin{pmatrix} e_{1t} \\ e_{2t} \\ e_{3t} \\ e_{4t} \end{pmatrix} \qquad (5)$$

$$\bar{R}^2_{LNGDP} = 0.9983 \quad \bar{R}^2_{LNT} = 0.9913 \quad \bar{R}^2_{LND} = 0.9844 \quad \bar{R}^2_{LNL} = 0.9969$$

Table 4 The results of the Granger Causality Test between factor inputs and economic growth

Null Hypothesis	F Statistic	P Value	Conclusion
ΔLNT not Granger cause ΔLNGDP	6.78428	0.0006	Reject
ΔLNGDP not Granger cause ΔLNT	6.89831	0.0006	Reject
ΔLND not Granger cause ΔLNGDP	2.14001	0.1072	Reject
ΔLNGDP not Granger cause ΔLND	0.81540	00539	Accept
ΔLNL not Granger cause ΔLNGDP	3.33409	0.0006	Reject
ΔLNGDP not Granger cause ΔLNL	2.72883	0.0006	Reject
ΔLND not Granger cause ΔLNT	2.01025	0.1247	Reject
ΔLNT not Granger cause ΔLND	0.65728	0.5823	Reject
ΔLNL not Granger cause ΔLNT	1.97726	0.1296	Reject
ΔLNT not Granger cause ΔLNL	3.90781	0.0140	Reject
ΔLNL not Granger cause ΔLND	3.70143	0.0177	Reject
ΔLND not Granger cause ΔLNL	0.66486	0.5777	Accept

Source: Authors

The Impulse Response Function

An impulse response is that by the conduction of the dynamic structure model of VAR, applying one standard deviation shock to the perturbation to affect the current value and a future value of endogenous variables, and the impulse response function describes the response of each endogenous variable to the error shock. In order to analyze the dynamic relationship of electricity investment and economic growth based on the VAR (2) vector autoregressive model, we construct the impulse response model of electricity investment; other investment, labor and economic growth (Equation (6)).

Here, k represents the lag order, and means the random disturbance, namely the innovation. In order to avoid the influence of the variable order on the analysis result, the generalized impulse method is used to obtain the corresponding function. In Figure 4, the horizontal axis represents the number of the follow-up period of the impulse response function, and the vertical axis represents the degree of the response to the shock from explanatory variables to explained variables. In order to save space, this paper analyzes the impulse response combined diagram of electricity investment and economic growth. The diagram shows that the GDP responses most strongly to the impact of the change of itself, and always keeps being positive; the impact response reaches the highest in the second stage, only to start gradually decreasing to the sixth and seventh to the lowest, and then beginning to rise slowly from the seventh stage. The response of the

$$\begin{cases} LnGDP_t = \sum_{i=1}^{k} a_{11} LnGDP_{t-i} + \sum_{i=1}^{k} a_{12} LnT_{t-i} + \sum_{i=1}^{k} a_{13} LnD_{t-i} + \sum_{i=1}^{k} a_{14} LnL_{t-i} + \\ LnT_t = \sum_{i=1}^{k} a_{21} LnGDP_{t-i} + \sum_{i=1}^{k} a_{22} LnT_{t-i} + \sum_{i=1}^{k} a_{23} LnD_{t-i} + \sum_{i=1}^{k} a_{24} LnL_{t-i} + \zeta \\ LnD_t = \sum_{i=1}^{k} a_{31} LnGDP_{t-i} + \sum_{i=1}^{k} a_{32} LnT_{t-i} + \sum_{i=1}^{k} a_{33} LnD_{t-i} + \sum_{i=1}^{k} a_{34} LnL_{t-i} + \zeta \\ LnL_t = \sum_{i=1}^{k} a_{41} LnGDP_{t-i} + \sum_{i=1}^{k} a_{42} LnT_{t-i} + \sum_{i=1}^{k} a_{43} LnD_{t-i} + \sum_{i=1}^{k} a_{44} LnL_{t-i} + \zeta \end{cases} \quad (6)$$

GDP to the other investment in the first period is the strongest, only to start gradually decreasing, becoming negative in the fourth period, indicating that, after a shock by the external conditions, another fixed-assets investment will have an impact on economic growth in the same direction in a short term, which effect will last for 4 periods. The response of the GDP to electricity investment in the former 4 periods has a positive effect, and it becomes the biggest in the second period, indicating that, after electricity investment is subject to external shocks, economic growth will be impacted in the same direction, and after the transmission of the industrial chain, it is enhanced in the second period.

The impulse response of the standard innovation of electricity investment to the GDP is positive in the former 5 periods and reaches the maximum in the second period only to begin to decline, and in the fifth period to the eighth period, it becomes negative while it grows slowly in the eighth period, indicating that economic growth has a positive impact effect on electricity investment in a short term, but with a longer duration effect, and it will have a longer-lasting effect. The impulse response of the standard innovation of electricity investment to itself reaches the maximum in the second period, and then it starts to decline and starts becoming negative in the fourth period. The impulse response of the standard innovation of electricity investment to other investment is positive in the former 4 periods and reaches the maximum in the second period. So, a positive impact on economic growth, investment and other investment of the current will bring a positive impact on electricity investment in a short term, whereas the shock will be enhanced after the market's reaction in the first period.

Variance Decomposition

In order to further analyze the degree of the contribution of each structural impact on the change of endogenous variables, and in order to evaluate the importance of different structural shocks, the model is subject to variance decomposition. Tables 5 and 6 and Figure 5 show that the LNGDP in the former 3 periods can mostly be explained by its own innovation, but the explanatory power declines from 100% in the first period to 29% in the tenth period.

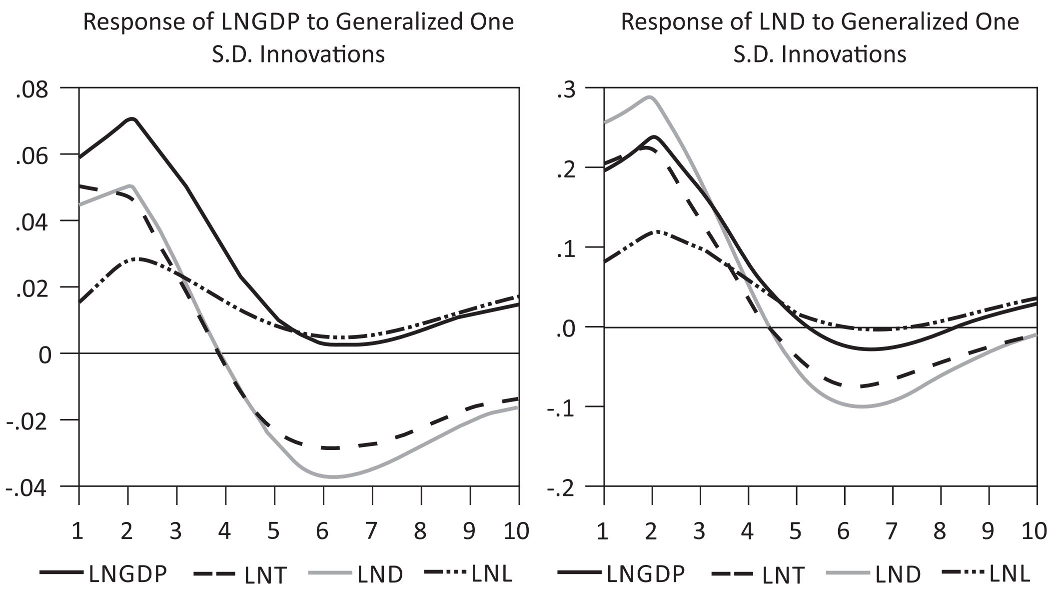

Figure 4 The Combined Diagram of the Generalized Impulse Response

Source: Authors

Table 5 The Variance Decomposition of the LNGDP

Period	Standard Error	*LNGDP*	*LNT*	*LND*	*LNL*
1	0.059197	100.0000	0.000000	0.000000	0.000000
2	0.096269	91.67138	7.227912	0.646941	0.453765
3	0.118709	79.88867	18.77865	0.440138	0.892535
4	0.134991	66.13909	31.08714	1.620644	1.153123
5	0.151206	53.17477	40.36154	5.237497	1.226192
6	0.166860	43.68617	46.04092	9.028581	1.244330
7	0.180026	37.55150	49.70251	11.42625	1.319746
8	0.190547	33.65200	52.38870	12.45309	1.506203
9	0.199396	31.06850	54.44583	12.66037	1.825300
10	0.207477	29.17846	56.02830	12.51836	2.274878

Source: Authors

Table 6 The Variance Decomposition of LND

Period	Standard Error	*LNGDP*	*LNT*	*LND*	*LNL*
1	0.254069	57.40740	9.917013	32.67559	0.000000
2	0.389281	61.76108	5.338264	32.44165	0.459005
3	0.441256	63.35271	4.432909	31.25446	0.959921
4	0.454702	62.47016	6.643627	29.55670	1.329513
5	0.468820	58.76720	10.47461	29.30905	1.449142
6	0.488767	54.45250	13.83929	30.28974	1.418467
7	0.505067	51.31187	16.19463	31.10424	1.389258
8	0.514703	49.43951	17.86401	31.27344	1.423038
9	0.520673	48.36449	19.11299	30.98424	1.538279

Source: Authors

In contrast, three kinds of the capital input explain more economic growth; the explanatory power of electricity investment increases from 0.65% in the second period to 12.7% in the ninth period, and the explanatory power of other fixed-asset investment reaches 56% in the tenth period, indicating that the contribution of a fixed asset investment, including electricity investment, to economic growth gradually strengthens in the late economic development, and the impact is slow and lasting, which has a profound

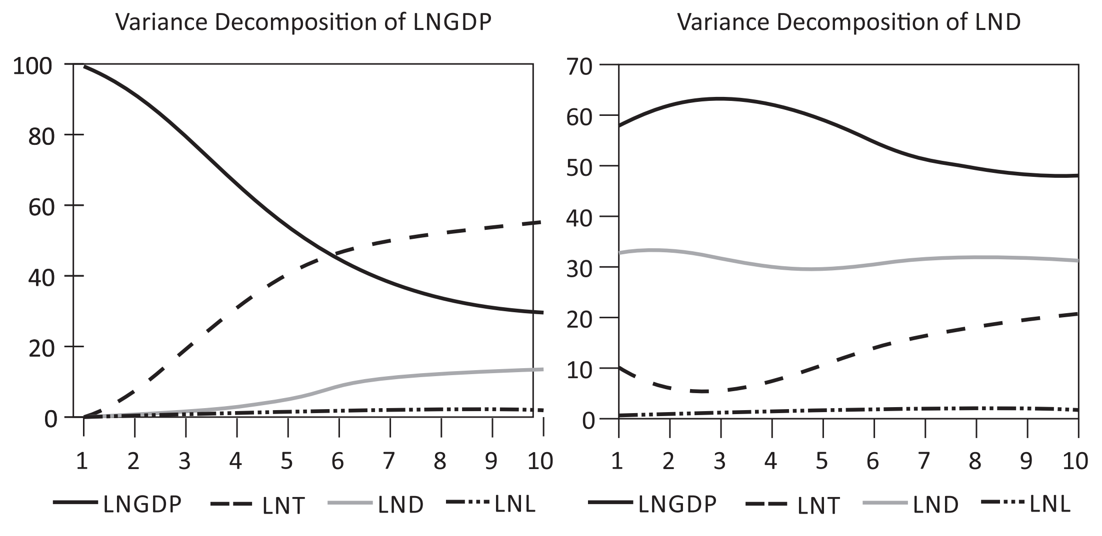

Figure 5 Combined Diagram of Variance Decomposition

Source: Authors

and important influence on China's economy. This is mainly because of the fact that the impact of electricity investment on economic development gradually takes effect through the development of every link of the upstream and downstream industry chains, and the stimulating effect on economic growth has a certain lag, but it is more durable.

To electricity investment, from 50% to 60% is explained by economic growth in the former 7 periods, and economic growth gradually becomes weak later, still remaining 47% in the contribution rate until the tenth period, indicating that investment growth depends on a long-term and stable economic development. The explanatory power of electricity investment on itself almost remains at a stable level of about 30% in 10 periods, reflecting that construction and investment in electricity are long-term and consistent.

The Vector Error Correction Model (VEC)

According to the results of the co-integration test and the Granger causality test, the vector auto-regression model is modified and the vector error correction model is constructed to reflect the influence of the short-term fluctuation of the variables on the explained variables on the restrictive conditions of co-integration. Table 7 shows the estimation results of the VEC (2) model.

Table 7 The estimation results of various investments and economic growth sequence VEC (2) Model

Explanatory Variables	*Model (1)* *D(LNGDP)*	*Model (2)* *D(LNT)*	*Model (3)* *D(LND)*	*Model (4)* *D(LNL)*
EC(error correction term)	0.2105[4.1751]	0.5242[3.2045]	0.741315[3.2050]	0.005176[0.23590]
(LNGDP(-1))	0.6480[2.3109]	1.8443[2.0272]	0.4417[0.3434]	-0.1041[-0.8527]
D(LNGDP(-2))	-0.6599[-2.3302]	-1.9328[-2.1034]	-1.7658[-1.3589]	0.01825[0.1480]
D(LNT(-1))	-0.1605[-1.8594]	-0.5250[-1.8743]	-0.1885[-0.4760]	-0.0512[-1.3619]
D(LNT(-2))	0.1400[1.5373]	0.3292[1.1139]	0.3792[0.9074]	0.0268[0.6749]
D(LND(-1))	0.1012[2.0969]	0.3754[2.3965]	0.5418[2.4458]	0.0510[2.4276]
D(LND(-2))	-0.0339[-0.6903]	-0.1085[-0.6810]	-0.2075[-0.9210]	-0.0308[-1.4429]
D(LNL(-1))	0.2560[0.7264]	0.6615[0.5784]	1.4128[0.8736]	0.1764[1.1495]
D(LNL(-2))	0.8413[2.599]	3.6924[3.515]	4.5730[3.0782]	0.1744[1.2379]
C	0.0538[2.6358]	0.0152[0.2300]	0.0289[0.3082]	0.0217[2.4479]
	Test of VEC Model for each Equations			
R^2	0.638329	0.599427	0.509422	0.248894
S.E.	0.054019	0.175285	0.247865	0.023512
F-statistic	9.216915	7.814673	5.422822	1.730492
Log l	90.96815	23.87473	4.125866	138.3815
AIC	-2.840988	-0.486833	0.206110	-4.504613
SC	-2.482558	-0.128403	0.564540	-4.146183
	Overall Test for VEC Model			
Log L=315.4788	AIC=-9.525573 SC=-7.948481			

Source: Authors

The error correction term reflects the adjustment of the long-term equilibrium to short-term fluctuations, and the adjustment coefficients of the error correction term of the 4 equations are positive, and the corresponding t values are all statistically significant except equation 4, indicating that a long-term co-integration relationship plays a significant role in promoting the current electricity investment and other investment in fixed assets, so the existence of a co-integration relationship (to maintain the long-term stability of the system) is conducive to the promotion of economic growth and the growth of capital. A long-term equilibrium relationship has a positive impact on the short-term fluctuations of economic growth, other investment, electricity investment and labor-force investment, while electricity investment and other investment are greatly impacted and are statistically significant, whereas the impact on the labor input is minimal and not statistically significant. According to Table 5, the VEC (2) equation (7) of economic growth is presented as follows: From Equation 7, the error correction coefficient is

$$\underset{}{d(LnGDP)} = \underset{(4.175)}{0.21\text{vec}} + \underset{(2.31)}{0.648\, d(LnGDP(-1))} - \underset{(-2.33)}{0.66\, d(LnGDP(-2))} - \underset{(-1.859)}{0.16 d(LnT(-1))} + \underset{(-1.537)}{0.14 d(LnT(-2))}$$
$$+ \underset{(2.097)}{0.101\, d(LnD(-1))} - \underset{(-0.69)}{0.034\, d(LnD(-2))} + \underset{(0.726)}{0.256\, d(LnL(-1))} + \underset{(2.599)}{0.841\, d(LnL(-2))} + \underset{(2.636)}{0.054} \quad (7)$$

significantly positive, indicating that a variety of investments can promote long-term econ3mic growth with an annual adjustment of 21%. From the coefficient of the explanatory variables, the coefficients of and are significant, indicating that, in the constraints of the long-term stability of the system, electricity investment, the labor input can promote economic growth in a short term.

THE INFLUENCE OF SMART GRID INVESTMENT ON ECONOMIC GROWTH - SCENARIOS SIMULATION BASED ON THE VAR MODEL

The estimation of the VAR model and the analysis of the impulse response function and the variance decomposition above are to find the law of a mutual influence between each input and economic growth, thus providing a basis for forecasting a trend of each index in the future periods. In order to predict the impact of the mode of China's electricity investment on economic growth in the future, according to the VAR model established, the forecast of the impact of the different scenarios of the investment plan from 2013 to 2020 on economic growth is made.

Model Fitting

In order to test the accuracy of the model predictions through the sample forecast, a comparison between the actual value of the endogenous variables and the predicted value of the model was made to obtain the fitting result of the VAR model, which indicates that the fitted and the actual values are highly consistent, so the model (Figure 6) can be used in the future to make economic forecasts.

The forecast of economic growth in different investment scenarios

Assuming that the VAR estimating equations above remain unchanged in the future, the effects of different electricity investment on economic growth are predicted. Taking the forecast of the original VAR model as the baseline scenario, the three different investment projects are compared with the situation. According to the baseline scenario, all variables are endogenous variables in the VAR vector auto regression model and the equation of each endogenous variable is not dependent on its current value, so, no sample external data is needed to predict the value of a variable and the electricity investment equations in the VAR modes are deleted to become exogenous variables in the other three scenarios. The scenarios set of the investment model is referred to HAN Dong, YAN Zheng, SONG Yiqun, SUN Qiang and ZHANG Yibin (2012) for the assumptions of a smart grid investment program, and the investment projects are divided into the S type investment[1], the negative index investment and the annual investment, and the cumulative total investment of the three programs is equal. According

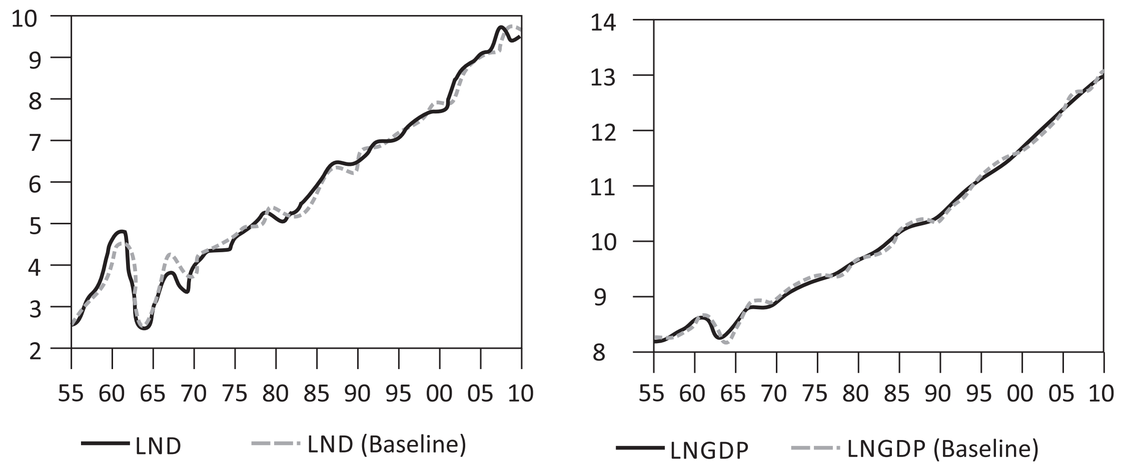

Figure 6 The fitting of the static predictive value and the actual value

Source: Authors

to the *Review Report of Twelfth Five-Year Plan for Electric Power Industry,* China's national electric power industry investment plans were 6.1 trillion yuan and 7.1 trillion yuan in the periods of the Twelfth Five-Year Plan and the Thirteenth Five-Year Plan. After deducting the actual investment of 2011 and 2012, the cumulative total electricity investment from 2013 to 2020 is 10586.1 billion. The cumulative investment is allocated to each year according to the investment situation above to predict other endogenous variables in the model. Considering the purpose of this study, Figure 7 only shows the trend of the corresponding GDP forecast values under the four investment scenarios.

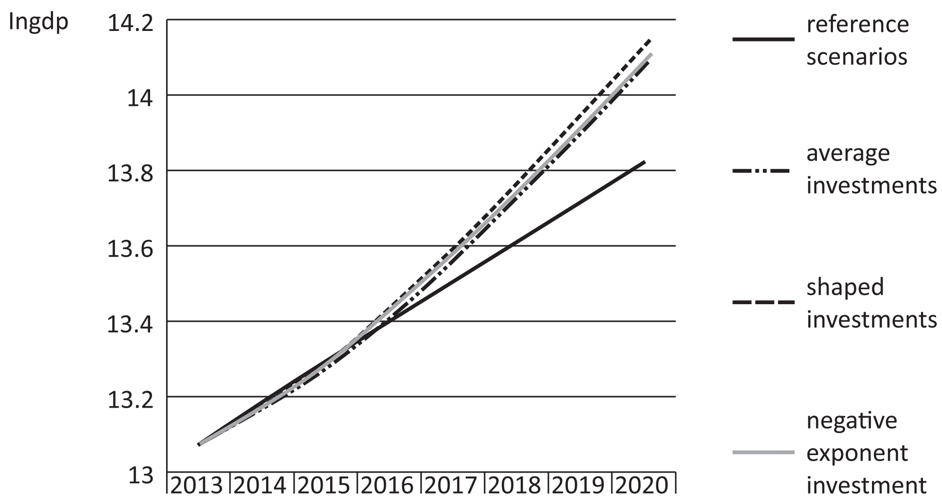

Figure 7 Forecasting of LNGDP under the different investment scenarios

Source: Authors, based on: *The Review Report of Twelfth Five-Year Plan for Electric Power Industry*

The investment data in this figure are from the Review Report of Twelfth Five-Year Plan for Electric Power Industry.

According to the total investment of the electric power industry in the forecast periods, the investment of each period is calculated by using the regression method of the general equations through the annual investment, the S investment and the negative index investment, which is then substituted into the VAR model, respectively, to obtain the predicted value of the LNGDP. The log will not affect the trend of the variable, so the change trend of the LNGDP reflects the change of the GDP. Figure 7 shows that the variation of the electricity investment scheme has an obvious influence on the economy. The prediction results show that the value of the predicted curve of the LNGDP under the S investment project is maximum, which has a strong role in promoting economic growth. This is because under the S investment plan, investment has a rapid growth in the middle stage, and it tends to be stable in the late one. This kind of investment timing complies with the law of the development of the technical economy, so investment makes a better effect.

CONCLUSION

In order to study the relationship between electricity investment and economic growth, investments are decomposed into electricity and other investments in this article, and the labor factor is also taken into the C-D function. Based on the large sample of data from 1953 to 2012 and the VAR vector auto regression model, the impulse response function, the variance decomposition method and the error correction model are used to investigate a short- and long-term impact on economic growth from electricity investment, and different scenario forecasts of investment schemes are made according to the measurement results. The results show that:

- There is a long-term stable equilibrium relationship between the electricity industry investment, other investment, labor-force investment and economic growth. As the electricity industry investment can promote economic growth, China's smart grid construction in the present day and large investments in the electricity industry in the future will help to improve the situation of the financial crisis having brought downward pressure on economic development.
- The impulse response function of the VAR model is constructed, the results of which show that the impact of electricity investment on economic growth in the second year is the strongest, and this positive impact of will remain for four years. The positive impact of other investment on economic growth will also last for four years, and the strongest impact appears in the first year.
- The decomposition of the prediction error of the dependent variable in the VAR model shows that the contribution of fixed asset investment, including electricity investment, to economic growth in a later economic development gradually strengthens, the impact of which is slow and protracted. This is mainly because the multiplier effect of electricity investment is promoted through an interaction in the upstream and downstream industry chains.
- The error correction model shows that a long-term equilibrium relationship of the system is conducive to economic growth and the growth of a variety of capital investment. Under a long-term stable equilibrium relationship, electricity investment can promote economic growth in a short term.
- The scenario predicted results show that the choice of investment projects will affect the stimulating effect of electricity investment on economic growth, and the S-type investment project can be more effective in promoting economic growth.

ENDNOTE

1 S type investment means that the investment change trend is in the shape of the letter „S", in which the rate first increases and then decreases.

ACKNOWLEDGMENTS

This paper is sponsored by the NSF project „Research on the Influence of a Smart Grid on the Supply and Use of Energy and the Energy Industry Structure and the Development Strategy" (12AZD103).

REFERENCES

Barro, R. J. (2007). *Macroeconomics: A Modern Approach*. Mason, OH: USA, Thomson Higher Education.

Chen Sheng-Tung, Kuo Hsiao-I, & Chen Chi-Chung (2007). The relationship between GDP and electricity consumption in 10 Asian countries. *Energy Policy, 35*(4), 2611-2621. doi: 10.1016/j.enpol.2006.10.001

Fu Feng-Cheng, Vijverberg Chu-Ping C., & Vijverberg Wim P. M. (2004). Public infrastructure as a determinant of intertemporal and interregional productive performance in China. *IZA Discussion Paper* No. 1019, (2).

Greenwald, D. (1982). *Encyclopedia of Economics.* New York, NY: McGraw-Hill Book Company.

Han Dong, Yan Zheng, Song Yiqun, Sun Qiang, & Zhang Yibin (2012). Dynamic assessment method for smart grid based on system dynamics. *Automation of Electric Power Systems, 36*(3), 16-21.

Jiang Jin-he, & Yao Yu-fang, (2002). A quantitative analysis of the relations between China's economic growth and electric power development. *The Journal of Quantitative and Technical Economics, 19*(10), 5-10.

Johansen, S. (1991). Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models. *Econometrica, 59*(6), 1551–1580.

Khanna Mad-hu, & Rao Narasim-ha D. (2009). Supply and demand of electricity in the developing world. *Annual Review of Resource Economics*, 1, 567-596. doi: 10.1146/annurev.resource.050708.144230

Li Qiang, Wang Hong-chuan, & Hu An-gang (2013). Electricity consumption and economic growth in China causality analysis based on provincial panel data. *China Industrial Economy*, 9.

Liu Lun-wu (2005). Dynamic econometrical model and analysis on promoting effect of infrastructure investment on economic growth. *Jouranl of Applied Statistics and Management, 24*(2)

Liu, Bing-lian, Wu Peng, & Liu Yu-hai (2010). Transportation infrastructure and the increase in TFP in China - Spatial econometric analysis on provincial panel data. *China Industrial Economics*, 3.

Mankiw, N. G. (2006). *Macroeconomics*. USA: Worth Publishers Inc.

Peng Yu (2012). Economic growth electric power industry development and environmental pollution control. *Comparative Economic and Social Systems*, 5, 183-192.

Qu Xiao-yan, Zhang Shi-tong, & Wu Yan-yan (2011). The characteristics and status of the energy industry - Based on the input - output model. *On Economic Problems*, 2.

Ren Rong, Cheng Lianyuan, Xie Zhuoran, & Zong Gang (2012). Dynamic effect analysis on the relationship of transport infrastructure investment and economic development in China based on VAR model. *Science and Technology Management Research*, 4, 85-89.

Smith, A. (2000). *The Wealth of Nations.* Random House Group.

Zhang Lin, He Lian-chen, & Wang Jun-xia (2008). Electricity consumption and economic growth in China - Based on the 30 provincial panel data co-integration test. *Journal of Shanxi Finance and Economics University, 30*(12), 18-21.

Zhou, P., Ang, B. W., & Poh, K. L. (2006). A trigonometric grey prediction approach to forecasting electricity demand. *Energy, 31*(14).

Chinese Statistical Yearbook Database

China's Population and Employment Statistics Yearbook

New Chinese Sixty-Year Statistical Data Collection

The Outline of the Twelfth Five-Year Plan for Chinese National and Development Strategies (http://www.gov.cn/2011lh/content_1825838.htm)

The Review Report of Twelfth Five-Year Plan for Electric Power Industry

Received on 16th June 2014,
after revision,
accepted for publication on 19th August 2014.

Fan Yuxian is a PhD student at the School of Economics and Finance of Xi 'an Jiaotong University, Xi 'an, Shaanxi, China. The area of her scientific research is energy economics.

Yuan Xiaoling is a Professor, doctoral supervisor, at the School of Economics and Finance of Xi 'an Jiaotong University, Xi 'an, Shaanxi, China. The area of her scientific research are energy economics and urban economics.

He Songke, School of Economics and Finance of Xi 'an Jiaotong University, Xi 'an, Shaanxi, China.