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The short-run and dynamic relationship between urbanization, electricity consumption and economic growth

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ABSTRACT

In the process of urbanization, the dynamic relationship between Urbanization and economic growth may change over time. This paper is to examine the relationship between electricity consumption and economic growth under urbanization in China during 1980-2009. The gross fixed capital formation and the employment level are incorporated to build a multivariate analysis framework. The main contributions of this paper include: (1) Through Vector Error Correction Model, the short-term fluctuation of economic growth puts it 78.2% down to electrical input, investment and labor input, urbanization and adjustment by itself. (2) Impulse Response and Variance Decomposition techniques are employed to further analyze the internal relationship between electricity consumption and economic growth under urbanization. The research thus recommends that policies towards the expansion of electricity infrastructure should be intensified in China in order to meet the increasing demand exerted by the country's strong economic growth and rapid urbanization.

Key words: Economic Growth; Electricity Consumption; Urbanization; Impulse response function; Variance decomposition.

INTRODUCTION

With the processing of urbanization in China, energy consumption will change quickly. At the same time, power industry is a pillar industry, and electricity plays a very important role on the sustainable healthy coordinative and rapid development of its economy and society. Thus, more and more attention has been paid to analyze the dynamic relationship between electricity consumption and economic growth has caused widespread interests and dispute in both academia and industry recently. At present, the key point at issue is that whether electricity consumption Granger causes economic growth, or in the opposite way. The conclusions vary on different countries or regions at different periods. This is because different countries have different economic development policies, even if the same country would have different economic policies at different periods.

In recent years, although the co-integration test and Granger test were applied to examine the long-run equilibrium relationship and the causality direction between energy consumption and economic growth, their relationship has not reached a consensus. The causal relationship between the two has significant difference in different literatures with the use of different models and different testing methods, in different countries or regions, at different sample space and different time intervals. That is why the relationship between energy and economy has been extensively investigated by scholars in China and abroad. Kraft etc [1] started the econometric research of energy, specifically electricity consumption and economic growth. They found that there exists unidirectional causality running from GNP to energy consumption, applying Sims test method based on American data from 1947 to 1974. The result indicated that the implementation of energy conservation policies would not affect the growth of GNP, and the United States can implement energy conservation policies. However, Akarca etc [2] did not get similar results using the sample data 2 year less than data of Kraft etc[1]. Yu etc [3] discovered that causality did not exist between GNP and energy consumption, analyzing data of the U.S. in the period 1947-1978. This means that the choice of the sample space may affect empirical results of the causal relationship between electricity consumption and economic growth. In summary, there are the following different views on the relationship between energy (electricity) consumption and economic growth:(1)Energy (electricity) consumption is the Granger cause of economic growth[4], (2)Economic growth stimulates energy (electricity) consumption[5], (3)There is bidirectional causality between energy (electricity) consumption and economic growth[6], (4)There is no causal relationship between energy (electricity) consumption and economic growth[2-3].

These literatures studied the relationship between electricity consumption and economic growth, ignoring the rapid urbanization process in China. However, studying the impact of urbanization on electricity consumption and economic growth has important practical significance. Thus, some energy economists carried out research on the influence of urbanization. Liang [7] studied the influencing factors of energy consumption on different stages of urbanization using cointegration analysis. Economic growth was the most decisive factor of energy demand, but these two literatures did not consider the influence of economic growth on energy consumption when studied the causal relationship between urbanization, industrialization and energy consumption. Sun etc [8] established a predicting model of energy demand by support vector regression (SVR) and simulated the evolution of energy demand under different growth of explanatory variables. However, this paper did not study the relationship between urbanization, energy consumption and economic growth.

The previous research has the following limitations: (1) some researchers mainly studied the causal relationship and the long-run equilibrium relationship between electricity consumption and economic growth in the process of urbanization, and didn't conduct further research on the dynamic relationship between urbanization process, electricity consumption and economic growth. (2) some studies applied bivariate analysis but ignored some important configuration variables, as well as the substitution effects existing between the energy and other inputs . The introduction of these new variables would change the conclusions reached under the bivariate analysis framework.

However, with the acceleration of China's urbanization process, the interaction between electricity consumption and economic growth may change at a certain extent. The paper aims to answer the following questions: how does this interaction change and what impacts will the acceleration of urbanization bring to electricity consumption and economic growth? There already has been a small amount of literature studying the causal relationship between electricity and economy in the process of urbanization, but they drew very different conclusions.

Based on the latest research outcomes in China and abroad, this paper aims to employ some effective methods recommended by latest econometric references, to model the causal relationship between China's power consumption and economic growth in the process of urbanization, taking into consideration the five important variables of GDP, electricity consumption, gross fixed capital formation, employment levels and urbanization rate. Then error correction model, impulse response and variance decomposition technique are adopted to analyze the interaction rules of electricity consumption and economic growth in urbanization process. Finally, reasonable policy recommendations are put forward for government decision-making departments.

VARIABLES, MODEL AND DATA

In order to study the dynamic relationship between electricity consumption and economic growth in the process of urbanization, we introduce gross fixed capital formation and employment level as two new variables, establishing multivariate analysis framework based on the production function. The dynamic relationship between electricity consumption and economic growth in the process of China urbanization can be expressed as:

$$\ln \mathrm{Y} = g(\ln \mathrm{K}, \ln \mathrm{L}, \ln \mathrm{E}, \ln \mathrm{U}) \qquad (2)$$

Where Y represents the actual total GDP, K, L, E, U denote the actual gross fixed capital formation, the level of employment, the total electricity consumption and the level of urbanization in the form of urban population over total population respectively. In order to see the flexibility easily and eliminate variation in the results, $\ln \mathrm{Y}$ 、$\ln \mathrm{K}$ 、$\ln \mathrm{L}$ 、$\ln \mathrm{E}$ 、$\ln \mathrm{U}$ represent the logarithms of the corresponding variables respectively.

In this study, we use error-correction equation to test for long-run causality when the two variables are cointegrated and the variables are stationary only after differencing. The detailed model is as follows:

$$\Delta y = a + \sum_{i=1}^{k} \gamma_i \Delta x_{t-i} + \sum_{i=1}^{k} \delta_i \Delta y_{t-i} + \eta_1 \varepsilon_{t-1} + u_t \qquad (3)$$

where y and x are natural logarithms of variables, k is the number of lags, and ε_{t-1} is the lagged value of the error term from the cointegrated regression:

$$\ln(y)_t = \pi \ln(x)_t + \varepsilon_t \tag{4}$$

In this study, we choose the time-series data in the range of 1980-2009. The data is collected from "China Statistical Yearbook" (various issues) and Chinese energy statistics. The specific value and construction of each variable are as follows: 1) Real GDP (Y): from "China Statistical Yearbook", and we take 1980 as the base year to generate real GDP (Unit: 100 million). 2) Power consumption (E): from China energy statistics (Unit: 100 million KWh). 3) Gross fixed capital formation (K): from "China Statistical Yearbook" (Unit: 100 million), accounted by expenditure approach. We take 1980 as the base period and translate data into constant prices. The standard Chinese statistics report the price index of investment in fixed assets after 1991 and physical capital deflation indexes from 1980 to 1990 can be found in Hsueh and Li (1999). 4) Employment levels: from "China Statistical Yearbook" and we take the number of employees in each year(Unit: million).5) Urbanization process: comes from "China Statistical Yearbook". The process of urbanization is usually evaluated by the rate of urbanization, and urbanization rate = urban population / total population.

RESULTS ANALYSIS OF VECTOR ERROR CORRECTION MODEL

Using ADF test and cointegration test, we can extract a cointegration equation as followed (what in brackets are standard deviation):

$$\ln Y = 1.008 \ln E + 0.1470 \ln K + 0.6597 \ln L + 0.4121 \ln U - 6.9467$$
$$(0.1619) \quad (0.1290) \quad (0.1165) \quad (0.2901) \tag{5}$$

Table 1 estimation results of vector error correction model (Figures in brackets are standard deviation)

Error Correction	D(LNY)	D(LNK)	D(LNL)	D(LNE)	D(LNU)
CointEq1	-0.079985	0.215210	-0.049298	0.042408	-0.003572
	(0.03776)	(0.14631)	(0.03674)	(0.02314)	(0.04766)
D(LNY(-1))	-0.107785	-1.426996	0.779326	-0.468012	0.580143
	(0.43917)	(1.70171)	(0.42727)	(0.26917)	(0.55438)
D(LNY(-2))	0.631382	-1.820830	0.517797	-0.250942	-0.002234
	(0.52650)	(2.04010)	(0.51224)	(0.32269)	(0.66462)
D(LNK(-1))	-0.044173	1.122818	-0.723175	0.226321	0.030937
	(0.18646)	(0.72252)	(0.18141)	(0.11428)	(0.23538)
D(LNK(-2))	-0.281988	0.204244	0.087963	0.084899	-0.193795
	(0.20276)	(0.78565)	(0.19726)	(0.12427)	(0.25595)
D(LNL(-1))	-0.415092	0.462104	0.084913	0.070988	-0.156046
	(0.27120)	(1.05084)	(0.26385)	(0.16622)	(0.34234)
D(LNL(-2))	-0.014644	0.390142	0.166628	-0.024855	0.098076
	(0.16869)	(0.65366)	(0.16412)	(0.10339)	(0.21295)
D(LNE(-1))	0.467244	0.815647	0.003663	0.147284	0.221741
	(0.31920)	(1.23685)	(0.31055)	(0.19564)	(0.40294)
D(LNE(-2))	-0.315375	1.182971	-0.428788	-0.002698	-0.087629
	(0.28098)	(1.08877)	(0.27337)	(0.17222)	(0.35470)
D(LNU(-1))	-0.431781	1.247433	-0.318719	0.397505	-0.111071
	(0.46749)	(1.81146)	(0.45483)	(0.28653)	(0.59013)
D(LNU(-2))	-0.338006	0.985370	-0.465613	0.547163	-0.341377
	(0.44874)	(1.73878)	(0.43658)	(0.27503)	(0.56645)
C	0.095244	0.019101	0.025777	0.019667	0.062526
	(0.04122)	(0.15973)	(0.04010)	(0.02526)	(0.05204)
R-squared	0.781896	0.295065	0.783722	0.540953	0.525820
Adj. R-squared	0.621952	-0.221887	0.625118	0.204318	0.178089
Sum sq. resids	0.005100	0.076576	0.004828	0.001916	0.008127
S.E. equation	0.018439	0.071450	0.017940	0.011301	0.023277
F-statistic	4.888580	0.570779	4.941385	1.606944	1.512144
Log likelihood	77.44200	40.87038	78.18340	90.65993	71.15200
Akaike AIC	-4.847556	-2.138547	-4.902474	-5.826661	-4.381630
Schwarz SC	-4.271628	-1.562619	-4.326546	-5.250734	-3.805702
Mean dependent	0.089756	0.124985	0.019084	0.029285	0.097718
S.D. dependent	0.029990	0.064637	0.029300	0.012670	0.025675
Determinant resid covariance		8.58E-19	Akaike information criterion		-25.53439
Determinant resid covariance		4.54E-20	Schwarz criterion		-22.41479
Log likelihood		409.7143			

After inspecting cointegration relationship, we further establish the vector error correction model (VECM) (Table 1) linking the short-run fluctuations and the long-run equilibrium. In the short-run dynamics equation of real income, the coefficient of determination is 0.782, which indicates the volatility of real GDP growth can be explained 78.2% by the short-run fluctuations of 5 variables as well as the long-run relationships between them during the sample period. The error correction coefficient CointEq1 in Table 3 represents each variable's correction level of the deviation from long-run equilibrium in the previous period. Table 3 shows CointEq1 in the error correction equation is significantly different from zero at the 5% level. This means that there tends to be a long-run equilibrium between China's economic growth, electricity consumption, gross fixed capital formation, employment level and urbanization during the sample period, that is, they will take responses in period T to the deviation from its long-run equilibrium level in period T-1. They all are not weak exogenous variables about the long-run parameters.

DYNAMIC ANALYSIS OF THE RELATIONSHIP BETWEEN URBANIZATION, ELECTRICITY CONSUMPTION AND ECONOMIC GROWTH

(1)Impulse response function

Based on the previous analysis framework, this paper uses the impulse response function to study dynamic relationship between China's power consumption and economic growth in the process of urbanization. According to the impulse response methods and backup options of functions provided by Eviews6.0, we select the Cholesky decomposition to analyze the response level of one standard deviation of electricity consumption, gross fixed capital formation, employment level, urbanization to economic growth. The detailed results are shown in Fig.1~ Fig.4.

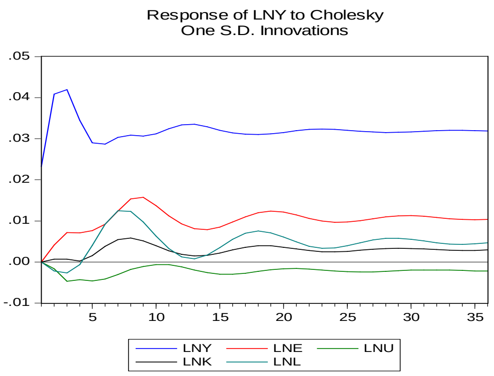

Fig.1: Impulse response of economic growth by fluctuations in other variables

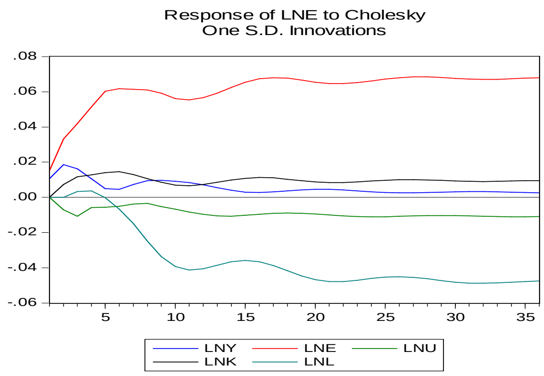

Fig.2: Impulse response of electricity consumption by self-fluctuations in other variables

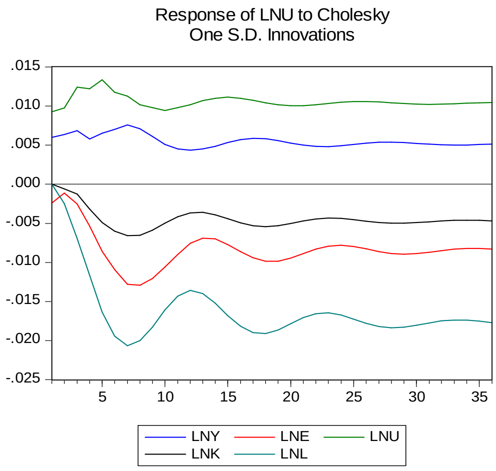

Fig.3: Impulse response of urbanization by other variables

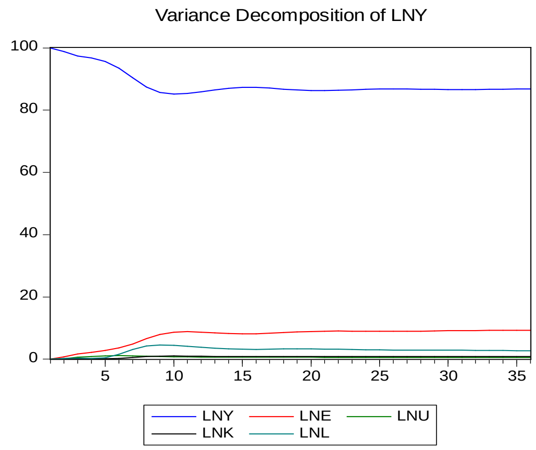

Fig.4: Variance decomposition graph of economic growth

According to Fig.1, we can learn about LNY's responses to one standard deviation of LNE, LNU, LNK and LNL. One unit shock to LNE will have positive effect on LNY from the second period, and then gradually rise, reaching the maximum in the ninth period. After that, the effect goes a downward trend and gradually converges. One unit shock to LNU will have negative effect on LNY from the second period, and the effect gradually increases until the third period, when it increases slightly after a temporary small decline. It is until the 11th period that the effect gradually converges. One unit shock to LNY itself will bring increasing effect to LNY from the first period and the effect reaches the maximum in the third period, then gradually decreases to converge in the 7th period. But the response level of LNY itself is the largest in the five variables, which reveals that LNY is greatly affected by itself.

LNE's responses to a standard deviation of LNY, LNU, LNK and LNL are shown in Fig.2. One unit shock to LNE will have positive influence on LNE from the first period, and the maximum comes in the second period, after which the influence gradually decrease to a stabilized state in the 6th period. One unit shock to LNU will bring a negative impact on LNE, reaching the maximum in the third period, and then gradually decrease to achieve a balanced state. One unit shock to LNE will positively affect itself in the first period, then gradually increase to achieve the maximum and a stabilized state as well in the sixth period. Influence caused by LNE on itself is the largest.

Fig.3 shows LNU's responses to a standard deviation of LNY, LNE, LNU, LNK and LNL. One unit shock to LNY will have positive effect on LNU beginning from the first period and remaining in a stable state. One unit shock to LNE has a negative impact on LNU starting from the second period. The impact reaches a maximum in the 7th period and then decreases slightly to achieve a balanced state. One unit shock to LNU has a positive influence on the LNE from the first period, reaching the maximum in the third period, after which a slight decline occurs and it gradually comes to a stabilized state. In short, the process of urbanization greatly affects economic growth and electricity consumption. According to the "Northam curve" discovered and raised by American city geographer Ray.M.Northam, China is now in the second phase of urbanization, which is the acceleration stage of urbanization. With the rapid process of urbanization, there must come a new round of rapid growth of China's economy and electricity demand.

(2)Variance decomposition

What the impulse response function describes is the impacts one endogenous variable's shock brings to other endogenous variables in VAR model. And variance decomposition evaluates the importance of different shocks by analyzing the contribution of the changes each shock brings to endogenous variables. Therefore, the variance decomposition can give the information of importance of each random perturbation which affects the variables in the VAR model. Figure 5 is a view of variance decomposition of LNY.

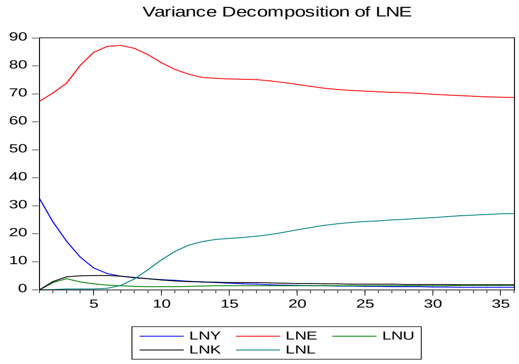

Fig.5: Variance decomposition of power consumption

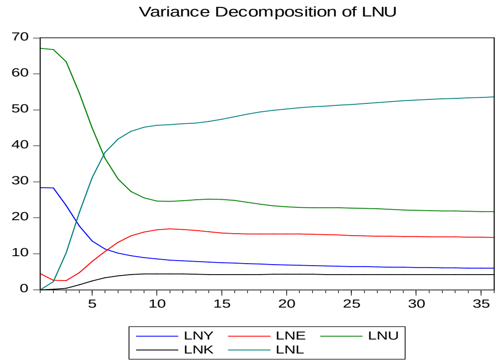

Fig. 6: Variance decomposition of urbanization

Fig.4 indicates that economic growth is only affected by its own fluctuations in the first period, and it depends greatly on the fluctuations. The shocks of LNE, LNU, LNK and LNL start to reveal in the second period, which means that electricity consumption, urbanization, gross fixed capital formation and employment level have delayed impacts on China's economic growth. Subsequently, the contributions to China's economic growth (LNY) of the electricity consumption LNE, urbanization LNU, gross fixed capital formation LNK, employment level LNL gradually increase, and the contribution rate of electricity consumption LNE finally stabilized at 9.2%. The decomposition result shows that urbanization process will influence economic growth greatly, and the contribution rate of urbanization to economic growth stabilizes at 0.5%.

As we can see from Fig.5, the contribution rate of urbanization to electricity consumption is increasing in the former three periods with a maximum of 3.9%. The contribution rate of economic growth to power consumption is the largest at first, reaching to 32.66%, and then decreases, tending to a stabilized state. The effect on electricity consumption by its own fluctuations is relatively large, which gradually increases in the former seven periods and then decreases to reach a steady state.

According to Fig.6, the contribution rate of power consumption to urbanization is decreasing in the former three periods. It begins to increase from the 4th period, achieving a maximum in the 11th period. After that, there is a slightly decrease before coming to the stabilized state. The contribution rate of economic growth to urbanization is the largest at beginning, reaching 28.35%. Then it gradually reduces to a stabilized state. The influence on urbanization by itself is also relatively large.

CONCLUSIONS

This paper analyzed the dynamic relationship and trends between China’s electricity consumption, gross fixed capital formation, employment and urbanization in the period of 1980-2009, through applying VECM, impulse response function and Variance decomposition, and further revealed the influence of urbanization process on electricity consumption and economic growth. The conclusions have been made in terms of empirical and analytical solutions.

Firstly, there exists long-run equilibrium relationship between China's GDP, electricity consumption, gross fixed capital formation, labor and urbanization, which complies with the empirical result of [7] about the long-run equilibrium relationship between China's economic development and power consumption.

Secondly, the impulse response and variance decomposition technology is applied to further study the impact of urbanization on electricity consumption and economic growth. With the rapid urbanization process, a new round of rapid economic growth and sustainable increase of electricity demand must occur. Urbanization will make a big contribution to electricity consumption and economic growth.

Based on the above conclusions, we put forward a few policy recommendations. China is a big country on electricity consumption, but per capita electricity consumption is relatively low. Electricity supply has become a bottleneck on China's economic development. The empirical results show that there is bidirectional Granger causality and long-run cointegration equilibrium relationship between China's power consumption and economic growth in the process of urbanization. With the acceleration of urbanization, electricity consumption and economy growth will speed up further. Therefore, government should strengthen its work on the following aspects.

Firstly, power infrastructure needs to be strengthened in order to promote economic growth. More than 85% of electricity is used in production, both surplus and shortage of electricity will bring enormous cost to the economy. And, the cost of shortage is much higher than the cost of surplus. That is to say, the loss of the same percentage power shortage is much greater than the investment required to solve the shortage problem, and this loss of shortage does not contain the adverse effects on social stability and the investment environment, which will enlarge the cost if we take these into account[7]. In order to maintain rapid and steady economic growth, we need to establish the development strategy of "power first" in power investment.

Secondly, it is a key period for China’s entry into the ranks of middle-income countries from now to 2020. Because of the energy and environment constraints, we need to not only meet the rapid increasing power demand, but also gradually change the extensive, highly dependent on energy and low energy efficiency way of economic growth. To complete the transformation of the development way, low-carbon power development in China should be progressive and self-restraint, which the government choose the bearable power structure and power cost considering China's economic development, social harmony and other aspects.

Thirdly, at this stage, the development strategy of power industry cannot be dissociated from the law of social development, and the impact of urbanization on electricity demand is obvious. With the acceleration of urbanization in China, power consumption will inevitably increase fast, which drives government to establish power development strategy and related energy policies considering urbanization process. Government cannot only regulate the appropriate speed of urbanization to control the growth of electricity demand, but also develop and implement positive power policies to improve power efficiency in the process of urbanization.

Fourthly, it is necessary to establish an early warning system for electricity. In the process of urbanization, a few high power-consuming industries deplete more than 60% electricity, which provides the possibility to build an early warning system. China's power consumption growth is greatly influenced by a handful of large consumers, which provides a good information source for the early warning of power shortage. In addition, industry structure, sector investment, prices change of large consumers and other information can be effective in providing early warning prior to the upcoming power shortage. If an early warning system has 1-2 years to provide early warning in advance, the government will have sufficient time to resolve the shortage problem or minimize the impact of power shortage.

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