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Dynamic Relationship between Urbanization and Energy Consumption in China: Based on PVAR Model

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Abstract

In this paper, authors analyzed the dynamic relationship between energy consumption and urbanization using PVAR model with panel data unit root tests, co-integration tests and panel VAR estimate based on provincial panel data from the year of 1990 to 2010 in China. The results show that: (1) there is a long-run co-integration relationship between Urbanization and energy consumption in the eastern, middle and western regions of China. (2) The impact of urbanization on energy consumption is significantly different in the three regions. The strongest effect is in the eastern area, followed by western area and middle area. In order to promote the harmonious development of Urbanization and energy consumption, China should improve the energy use efficiency and develop energy consumption policies according to the different relationships between urbanization and energy consumption in the eastern, middle and western areas.

Keywords: urbanization, energy consumption, panel data VAR model

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INTRODUCTION

The urbanization in China has developed rapidly since the reform and open. The number of population in cities has exceeded that of the rural area for the first time since the end of 2011 according to the data from State Statistical Bureau. The number of urban population has increased to 51.27% from 17.92% in 1978. According to Northam Curve, the urbanization and modernization of a country has entered high speed developing period when its urbanization level is among 30% to 70% and the per capita energy consumption will also increase rapidly. In 2010, China has become the no.1 energy consumption country exceeding the USA for the first time, consuming one fifth energy of the world. At the same time, the industrialization and the investment for urban development will keep pace with the urbanization. On the other hand, urbanization improves the efficiency of public infrastructure utilization, which will decrease the volume of energy consumption. The effect of the two different directions makes the relationship between urbanization and energy consumption become complicated. Therefore, studying the interdependence of urbanization and energy consumption can help to enhance the energy safety and speed up the process of urbanization, set up proper energy policy and realize economic growth steadily.

LITERATURE REVIEW

With the rapid development of urbanization in China, the relationship between urbanization and energy consumption has been widely concerned by scholars. Many scholars have done a lot of research using different models, different samples, different time intervals, different parameters and hypothesis testing methods. Some scholars believe that urbanization will increase energy consumption. For example, Jones (1997) pointed out that industrialization and urbanization were accompanied by each other during the process of economic development. To some extent, the effect of urbanization on energy consumption was independent. The greatest single change in energy

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utilization came from personal traffic and urban passenger traffic aggravated the fuel consumption. Parikh and Shukla (1995) studied the problem of energy utilization during the process of urbanization in developing countries and selected panel data of developing countries between 1965 to 1987 to do research, the result of which showed that the urbanization process aggravated the energy consumption of sample countries and 1% fluctuation of urban population caused per capita energy consumption to change by 0.47%. Liu (2007) analyzed the resource consumption during the process of urbanization in Jiangxi province and found that the change of urbanization level in this province was the reason for Granger-causality test of the increase in per capita energy consumption and the improvement in urbanization level had a positive effect on per capita energy consumption. Peng and Lei (2010) obtained the long-term equilibrium equation of the relationship between urbanization and energy consumption based on the grey system Verhulst model. Wang et al. (2010) researched the different effect of urbanization on resource consumption and pollution emission under different developing level based on STIRPAT model, using the 1985-2009 years' panel data of the five places in Heilongjiang, Henan, Guangdong, Gansu and Shanghai. Dai and Liu (2011) studied the relationship between urbanization, energy utilization and CO_2 emission in 29 provinces of China based on STIRPAT and the result showed that urbanization had apparently positive effect on energy utilization and CO_2 emission during the years of 1995-2009 (Zhang and Lin 2012) did empirical analysis on the impact of urbanization on energy consumption at the national and regional level using STIRPAT model and the provincial panel data in the years of 1995-2010. His analysis drew a conclusion that urbanization would increase the energy consumption of China. There are regional differences in the impact of urbanization on energy consumption, and the effect is descending from the eastern, middle and western areas. O'Neill et al. (2012) used IPETS model and CGE model to prove that the effect of urbanization on total emission and the proportion of energy consumption is slightly weaker.

The following scholars put forward that the impact of urbanization on energy consumption should be determined according to the development stage of the sample countries. The stage of national development is different, and the impact relationship is also different. Wei et al. (2003) pointed out that the urbanization promoted economic growth, improved people's living standard and increased the volume of energy consumption. But, at the same time, the improvement of urbanization also pushed the rational adjustment of the industrial structure, technological structure and product structure, optimized the allocation of resources and played a positive role in reducing energy consumption. Poumanyvong and Kaneko (2010) studied the effect of different urbanization stage on energy consumption based on STIRPAT model and the balanced panel data of 99 countries during the years of 1975-2005. The results showed that urbanization had a negative effect on the per capita energy consumption in low-income countries, while the impact on per capita energy consumption in middle-income and high-income countries was positive. Al-mulali et al. (2012), on the basis of FMOLS method and data of the years of 1980-2008, analyzed the long-term relationships between urbanization, energy consumption and CO_2 emission in seven large regions namely East Asia and Pacific, Eastern Europe and Central Asia, Latin America and the Caribbean, Middle East and North Africa, South Asia and Sub-Saharan Africa. The results showed that there was a long-term positive relationship between urbanization, energy consumption and CO_2 emission in the 84% of selected countries. In addition, the rest 16% of the selected countries is mixed results, among which there was a long-term negative relationship in some countries, there was no long-term relationship in low-income countries, and there was a uni-directional relationship in the other countries. Sadorsky (2013) selected 76 developing countries as samples to analyze the effect of urbanization on energy consumption intensity based on heterogeneous panel regression method. His empirical research proved that cities are different in scale and the effect of urbanization on energy consumption intensity is different. The impact of urbanization on energy intensity was statistically apparent in cities above certain scale.

All the above studied took use of static methods to analyze the relationship between urbanization and energy consumption. With the further research, some scholars believe that there is a dynamic relationship between urbanization and energy consumption. Liu (2007) established the vector auto regression model, using Granger Causality Test and co-integration analysis methods to research the long-term and short-term relationship between urbanization and energy consumption in China. The result was that the improvement of urbanization level was the reason of Granger Causality Test of the increase in energy consumption, there being a long-term equilibrium co-integration relationship between them. Huang (2009), Xu and Li (2010), Yuan et al. (2011) and Yang and Han (2012) analyzed the dynamic relationship between urbanization and energy consumption in Shaanxi province, Guanzhong city group, Gansu province, and Shandong province respectively and drew the similar conclusion. Al-mulali et al. (2013) researched the relationships between urbanization, energy consumption and CO_2 emission in the Middle East and North Africa during the years of 1980-2009. The results of Pedro Ronnie co-integration test showed that there was a co-integration relationship between urbanization, energy consumption and CO_2 emission and the results of dynamic least-square analysis also proved that there was a long-term bi-directional positive relationship between them. Zhang and Dang (2013) analyzed the nonlinear dynamic relationship between urbanization and energy consumption during the years of 1953-2011 based on the non-linear smooth transition model. His research results proved that the effect of urbanization on energy consumption would appear when the urbanization level is lower than 2.388% or higher than 15.3684%. Lin and Ouyang (2014) studied the determinants of China's energy demand during the process of rapid urbanization based on panel data model and co-integration model, and then forecasted China's energy demand based on scenario analysis. The results of his analysis showed that there was an inverse-U shape between energy demand and economic growth.

In summary, the authors of most existing literatures used static methods to analyze the unilateral relationship between energy consumption and urbanization. A few scholars have utilized dynamic methods, but most of them are limited to the discussion of individual provinces. China is large country, its different regions have different resources, different industrial structure. And the economic developing level is unbalanced, the urbanization level is different. Therefore, the relationship between urbanization and energy consumption in different regions may not follow the same rule. Meanwhile, just considering the uni-directional relationship between urbanization and energy consumption, there will be variable endogenous bias in the model (Pan and Ying 2012), which will lead to bias in the analysis results, and the policy recommendations drawn from it having no practical guiding significance. In view of the above, the authors of this paper selected provincial data of China in 1990-2015 and constructed panel data vector auto-regression model (PVAR) of urbanization and energy consumption, combining with the panel unit root test, panel co-integration test and panel VAR estimation to study the regional dynamic relationship between urbanization and energy consumption so that the research results will be more practically valuable.

RESEARCH METHOD AND DATA

Research method

Because traditional regression analysis cannot analyze dynamic relationship, Sims (1980) put forward Vector Auto-regression Model in 1980. This model regards all the variables in the system as endogenous variables. Every endogenous variable carries out regression analysis on their lagged value to estimate the dynamic relationship of all the endogenous variables through setting up simultaneous equation. On this basis, Holtz-Eakin put forward PVAR model based on panel data in 1988. This new method inherited many merits of the VAR model, and added individual effect variable indicating individual difference and time point effect variable showing the same attacks on different sections (Chen and Wang 2011). The PVAR model constructed in this paper is as follows:

$$y_{i,t} = a_0 + \mathring{a}_{j=1}^{k} b_i Y_{i,t-j} + d_i + f_t + u_{i,t} \quad (1)$$

Among the equation, $y_{i,t}$ is a vector including two variables $\{eny_{i,t}, urb_{i,t}\}$, $i = 1,2,\dots,N$ represents individual members, $t = 1,2,\dots,T$ means time span, d_i is individual effect related to regional characteristics such as position, natural condition or economy developing stage that might be omitted, f_t represents time effect showing the same attacks on different sections., k is lag intervals, and $u_{i,t}$ is random error term subjecting to normal distribution.

Variable Declaration and Data

There are two indicators measuring the urbanization level at preset. One is indicated by the proportion of non-agricultural population to the total population (urbanization ratio= non-agricultural population / total population) (Lin and Liu 2010). The other is measured by the proportion of urban population to the total population (urbanization ratio= urban population / total population). Because the two indicators' changing trend has no great difference, they are both used in existing research and the conclusion has no obvious contradiction (Liu 2007). According to the available data, the author of this paper uses the proportion of non-agricultural population to the total population to measure the urbanization level and the energy consumption includes final energy consumption, processing conversion consumption and energy loss.

Table 1. Results of panel unit root tests

Variables		LLC	Breitung t-statistic	IPS W-statistic	Fisher-ADF Chi-square	Fisher-PP Chi-square
Eastern area	lneny	1.088	1.705	-2.244	38.296	11.034
	lnurb	1.333	-1.608	1.2886	12.264	10.675
	D(lneny)	-5.690**	-4.029**	-1.516**	49.802**	45.296***
	D(lnurb)	-9.735***	-8.922***	-4.509***	59.957***	80.741***
Middle area	lneny	-1.561	1.368	-0.844	23.986	11.034
	lnurb	-0.872	-1.499	-0.022	20.475	18.344
	D(lneny)	-4.206***	-3.211***	-1.811**	31.065**	35.753**
	D(lnurb)	-7.903***	-7.326***	-4.4709***	51.533***	66.980***
Western area	lneny	-1.801	0.258	-2.128*	24.322*	9.579
	lnurb	-0.657	-1.162	0.58	11.889	7.558
	D(lneny)	-3.396***	-4.794***	-1.942**	26.138**	28.915**
	D(lnurb)	-4.214***	-3.956***	2.217**	30.368**	37.535***

NOTE : "D"refers to first order difference of the variables.
"*", "**", "***"represent significance degree under 10%, 5%, 1% level

The data of the total population and non-agricultural population is from *Almanac of China's Population* (unit: 10,000 people). The indicators listed in the almanac before 2000 are urban total population and urban non-agricultural population because of different statistic caliber, so the author used the conclusion of Zhou and Lin (2006) to modify the data while calculating the urbanization rate.

The energy consumption data of 1995-2009 is from *China Energy Statistical Yearbook* (unit: 10,000 ton standard coal). The energy consumption data of 2010-2015 is from *China Energy Statistical Yearbook* and the provincial yearbooks. The omitted data of Ningxia province in 2001 is modified by the average data.

Considering the imbalanced regional development in China, the authors study the eastern, middle and western areas respectively according to the statistic caliber of the national bureau of statistics. The eastern area includes Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Guangxi, Hainan province and so on. The middle area refers to Shanxi, Inner Mongolia, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, and Hunan province. The western area consists of Chongqing, Sichuan, Guizhou, Yunnan, Xizang, Shaanxi, Gansu, Ningxia, Qinghai, and Xinjiang Uygur autonomous region. Because there are no related data of Xizang autonomous region, Taiwan China, Hongkong China, Macao special administration region of China, and so is Chongqing city before 1966, the author didn't analyze the special administrative regions, Xizang autonomous region and Chongqing is included in Sichuang province.

At last, energy consumption is a physical indicator, but the urbanization is a proportional indicator, in order to eliminate the heteroscedasticity of variables and the fluctuation of data, the authors did logarithmic processing to the energy consumption and urbanization data, recorded as lneny and lnurb respectively.

RESULTS

Empirical analysis consists of three steps. Firstly, test the stability of the panel data with unit root tests. Secondly, do co-integration analysis if the data conforms to its terms to test the long-run equilibrium relationship between urbanization and energy consumption. Thirdly, do PVAR analysis to test bi-directional dynamic relationship between urbanization and energy consumption (Pan and Ying 2012).

Panel Data Unit Root Tests

The method of panel unit root tests mainly includes two parts. There are LLC (Levin & Lin & Chu) test, Breitung test, in terms of the same unit root process and IPS (Im & Pesaran & Shin) test, Fisher-ADF test, Fisher-PP test, in terms of different unit root process. All the tests have their advantages and disadvantages. The authors used the five testing methods to insure the stability of testing results. The results are as follows in **Table 1**.

From **Table 1** we can see that, under the 5% level, the horizontal value of the two variables (lneny and lnurb) of eastern, middle, and western areas can not reject the original hypothesis of the unit root, so the horizontal value of the two variables is unstable. The first order difference test for the two variables shows that they reject the original hypothesis of the unit root apparently under the 5% level. So the lneny and lnurb of the eastern, middle, and western areas are first order monintegral sequence. Further co-integration test can be carried out on the basis of the above tests.

Table 2. Results of panel Cointegration Test

Statistics		Eastern	Middle	Western
Intra Group Statistics	Panel v	-2.100**	-1.288*	-3.124**
	Panel rho	-2.493**	-1.723*	0.906
	Panel PP	-1.637**	-2.389**	-1.524**
	Panel ADF	-3.001**	-2.535**	-2.625**
Inter Group Statistics	Group rho	2.298**	1.797*	1.985*
	Group PP	-2.856**	-2.543**	-0.713*
	Group ADF	-3.781**	-2.010**	-1.473**

NOTE:"*", "**", "***"represent significance degree under 10%, 5%, 1% level

Table 3. GMM estimate results of panel PVAR

Variables	East		Middle		West	
	h_ eny	h_ urb	h_ eny	h_ urb	h_ eny	h_ urb
L.h_ eny	0.955 (0.150) [6.336]	0.062 (0.109) [0.566]	1.247 (0.112) [11.073]	0.084 (0.077) [1.078]	1.350 (0.119) [11.314]	-0.133 (0.130) [-1.024]
L.h_ urb	-0.097 (0.072) [-1.346]	0.837 (0.109) [7.672]	0.089 (0.181) [-1.490]	0.909 (0.185) [4.913]	0.129 (0.109) [1.184]	0.822 (0.115) [7.116]
L2.h_ eny	-0.143 (0.116) [-1.237]	-0.075 (0.082) [-1.908]	-0.353 (0.100) [-3.507]	-0.079 (0.064) [-1.230]	-0.489 (0.100) [-4.866]	0.122 (0.121) [1.003]
L2.h_ urb	0.239 (0.061) [3.916]	0.031 (0.040) [0.780]	0.168 (0.159) [2.054]	-0.030 (0.101) [-0.300]	0.005 (0.095) [0.058]	0.020 (0.031) [0.647]

NOTE : h_ means the variables have been done Helmert transformation. () is the standard deviation of the estimated coefficients. [] is the t-test value of the estimated coefficients. "L" is the first order difference. "L2" is the second order difference

Panel Co-integration Tests

According to the results of panel unit root tests, there can be long-run equilibrium relationship between lneny and lnurb, which need to be analyzed through panel co-integration tests. Considering the data characteristics of this paper, the authors used Pedroni co-integration testing method in terms of heterogenous panel data, constructing four statistical indicators and seven statistical methods to carry out panel co-integration test. The results of these tests are as follows in **Table 2**.

From **Table 2** we can see that the statistics of eastern area passed the significance test under 5% level and so is middle area under 10% level. The statistical indicator Panel rho didn't passed the significance test, but the indicators, Panel ADF and Group ADF, are more effective than the others according to the results of Monte Carlo simulation. So the failure of Panel rho has no effect on the results of panel co-integration tests of western area. To sum up, there is co-integration relationship between lneny and lnurb of eastern, middle, western area, at the same time, urbanization has enhanced energy consumption in the long run.

PVAR Estimation

PVAR consists of three parts. The first one is panel GMM estimation, which reflects the regression relationship between variables. The second one is variance decomposition of error terms, which illustrates the influence degree of the error term. The third one is impact response diagram, through which how the variables response to impact can be observed (Huang and Zhang 2007). The paper mainly focuses on quantitatively analyzing the dynamic relationship between urbanization and energy consumption, so the authors' analysis concentrates on the first two parts.

(1) GMM Estimation The time point effect and the individual effect in the PVAR model will lead to the deviation of the estimation coefficient, so cross section mean value difference method is used in this paper to remove the time point effect and Helmert transformation is used to eliminate individual effect. The lag period is determined to be 2 according to the criteria of AIC and SC. The estimated results are as **Table 3**.

Form **Table 3** we can see the results. Firstly, the effect of interregional urbanization on energy consumption has apparent difference. In the eastern area, one-period lagging urbanization has negative effect on the energy consumption, while the effect becomes positive in terms of two-period lagging and the effect is apparent under 10% level. The reason is, in the sample period, the eastern area is between the rapid development period and stable period of urbanization. In the early sample period, urbanization has a restraining effect on energy consumption along with the technical level improvement and the economic

Table 4. Results of variance-decomposition of PVAR

Variables	Periods	East		Middle		West	
		lneny	lnurb	lneny	lnurb	lneny	lnurb
lneny	10	0.769	0.231	0.961	0.039	0.812	0.188
lnurb	10	0.158	0.842	0.086	0.914	0.030	0.970
lneny	20	0.756	0.235	0.914	0.086	0.782	0.218
lnurb	20	0.155	0.845	0.082	0.918	0.034	0.966
lneny	30	0.758	0.242	0.907	0.093	0.781	0.219
lnurb	30	0.155	0.845	0.081	0.919	0.034	0.966

NOTE: the results come from 500 hundred times Monte Carlo simulation using Stata software

structure transformation. But energy consumption begins to pick up because of the rapid expansion of urban population and their excessive pursuit to the life quality. In the middle area, one-period and two-period lagging urbanization all have positive effect on energy consumption under 10% apparent level, which is because the middle area undertook some high-energy-consuming industries transferring from the eastern coastal areas during the process of urbanization. In the western area, urbanization has no apparent effect on the energy consumption. Secondly, energy consumption in the three areas has no significant effect on urbanization.

(2) Panel Variance Decomposition In this paper, in order to examine the interactive relationship between energy consumption and urbanization more accurately, the variance contribution rate of two endogenous variables fluctuation attacking different equations is obtained based on the variance analysis (Chen and Wang 2011). The results of variance analysis of the ten forecast periods, twenty forecast periods, and thirty forecast periods are given in **Table 4**.

The conclusions from **Table 4** are as follows. Firstly, the results of twenty forecast periods and thirty forecast periods have no significant difference, which means that the system has tended to be stable after twenty forecast periods (Huang and Zhang 2007). Secondly, the variance contribution of energy consumption and urbanization mainly comes from themselves and the rate keeps above 75%. Thirdly, when it comes to the urbanization contribution to energy consumption, the eastern area is about 23%, the western area is between 18%-22%, and the middle area is the least, below 10%. Fourthly, the energy consumption contribution to urbanization is slight, merely keeping between 3%-15%, the influence extent of which is the heaviest in the east, the second in the middle, and the slightest in the west.

It is because the regional development in China is imbalance and different area has difference urbanization level. During the sampling periods, the urbanization rates of the eastern, middle and western areas are 57.91%, 40.41% and 30.68% respectively. According to Ray. M. Northam's city development curve (Yang and Han 2012), some conclusions can be gotten. (1) The western area is at the primary stage of the urbanization process, the regional producing and living style is mainly about agriculture and rural areas. (2) The middle area is at the intermediate stage of the urbanization process, during which the size of the population continues to expand and the number of cities increases sharply. Their producing and living style is transferring from agriculture to industrialization. (3) The eastern area is in a rapid rise of the urbanization process. But some cities, such as Beijing, Shanghai, Tianjin, their urbanization rate being above 70%, have entered stable stage of urbanization process. The producing style of these cities has been changing from industry to service and their lifestyle has begun to focus on quality instead of quantity.

The interregional difference in producing and lifestyle leads to great difference in energy consumption mode. The western area focuses on the primary industry, consuming less energy, but its low urbanization level can't give full play to the scale economic effect of urban public construction. At the same time, the promotion of energy saving and environment protection technology is inadequate in the western area, which increases the energy consumption volume. While in the eastern area, non-farm population accounts for more than a half of the total population. A large number of urban population needs corresponding urban infrastructural facilities and their urban lifestyle makes daily energy consumption increase. Furthermore, because of the urban population's pursuit of life quality, more private cars are bought, average housing area is becoming larger and urban construction make the energy consumption increase. So urbanization affects the energy consumption of the eastern area most heavily, then the western area, at last is the middle area.

CONCLUSION AND POLICY IMPLICATION

In this paper, the authors constructed PVAR model and carried out sub-regional empirical analysis about the dynamic relationship between urbanization and energy consumption based on the provincial penal data between the years of 1990-2015 of China. The results of the study are as follows.

(1) There is a co-integration relationship between energy consumption and urbanization in the eastern, middle and western areas, which means that urbanization can promote the energy consumption in a long term.

(2) The results of panel GMM estimation shows that the effect of urbanization on energy consumption has apparent regional difference. The effect of urbanization on energy consumption in the eastern has changed from negative to positive. The effect in the middle area is positive and the effect in the western area is not so obvious.

(3) The results of panel variance decomposition shows that the system tends to stable after twenty forecast periods. The contribution of urbanization to energy consumption is the largest in the eastern area, the next in the western area and the smallest in the middle area. The contribution of energy consumption to the urbanization is very slight, and the order of contribution is the eastern, middle and western area in turn.

In order to promote the coordinated development of urbanization and energy consumption, the following policies are suggested based on the above study results. Firstly, improve the efficiency of energy utilization. At present, the total amount of energy growth is slowly and the competition from energy utilization is fierce, so improving the efficiency of energy utilization is the best choice to keep sustainable development of the economy. Secondly, according to interregional difference, suit proper measures to local conditions. Considering the eastern area is transiting from intermediate stage to stable stage, it is necessary to strengthen the construction of public infrastructure, improve the utilization efficiency, promote the publicity of environmental protection technology, and avoid using energy excessively due to the life quality improvement. As for the middle area, it being at the rapid rise stage of urbanization, there will be a blowout demand for energy. So frugal and economical developing policy should be implemented, strengthen the promotion of energy saving technology and enhance the environmental awareness of the population. While the western area is rich in energy reserves, it is still at the primary stage of urbanization. During its urbanization process, energy management should be strengthened and the utilization efficiency should be improved so as to realize the industrial structure transformation as soon as possible and avoid consuming energy excessively to push economic growth.

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