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Dynamic Analysis of Energy Consumption and Economic Growth Based on the PVAR Model

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A dynamic analysis of energy consumption and economic growth is carried out by using the PVAR model. Method the PVAR model is established to analyze the relationship between economic growth and energy consumption in the provinces and cities such as Beijing, Tianjin and Hebei. Results It is found that the relationship between economic growth and energy consumption is positive, and there is a difference between the energy consumption and economic growth among different regions. Conclusions The PVAR model is conducive to understand the dynamic relationship between regional economic growth and energy consumption, so it has the value of research and application.

1. Introduction

From 1970s to 1990s, there were three oil crises, which caused different degrees of impact on the global economy. In particular, the oil crisis in 1990 had a great impact on the global GDP. In order to cope with the subsequent economic crisis, many countries have studied the relationship between energy consumption and economic growth. According to the relevant research data and economic theory, it is known that energy consumption and economic growth are interrelated, and they can both promote and balance each other. From the situation of regional economic development in China, the imbalance of economic development between regions is relatively obvious. All circles of society pay attention to and study the relationship between economic growth and energy consumption so as to provide reference for the adjustment of the domestic economy and energy consumption structure. By playing a certain role in the study of the relationship between regional economy and energy consumption, the PVAR model mainly simulates the development history of unit economy by means of hypothesis and simulation, and studies the trend of economic growth according to the results of simulation analysis.
In this paper, the relationship between economic growth and energy consumption is mainly studied through the PVAR model. First, the PVAR model, related research theory and data model are discussed, and then the conclusion and the model realization of static panel data model are explored, and the relationship between economic growth and energy consumption is summarized.

2. Literature review

In the last half century, panel data model has made great progress. Panel data model has become an important branch of econometrics. Related theories, such as panel data unit root test theory, panel data co-integration theory, panel data causality test, mixed panel data model, static panel data model, dynamic panel data model, spatial panel data model, panel data error correction model, panel data vector autoregressive model, rotation panel data model and so on are becoming more and more mature. It has become a common research direction for scholars to discuss the macro and micro economic problems of countries in terms of panel data. With the maturity of the panel data vector auto-regression (PVAR) model, at present, a large number of achievements have been achieved in the application of the model. There are more and more literatures about using models to study socio economic problems both at home and abroad. Brana and others estimated the impact of global excess liquidity on the prices of commodities and assets in a group of emerging market countries by estimating the PVAR model. They defined global liquidity and emphasized the excess

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liquidity, and found that the global liquidity surplus had a spillover effect on the output and price levels of emerging countries (Brana et al., 2012). Lecturer and Egwaikhide used panel vector auto regression to investigate the impact of oil price volatility on the economic performance of five oil exporters in Africa. In order to study the response of impact, the study they did defined the following variables and sorted them. The variables are oil price fluctuation, real gross domestic product (real GDP), fiscal deficit, total investment and money supply. And then, they used standard Cureki factorization (Lecturer and Egwaikhide, 2014). Fauzel adopted panel vector auto-regression model (PVAR) to cater for the endogeneity and dynamics, and conducted research on the small island economy (Fauzel, 2016).

The early literature on the relationship between energy consumption and economic growth appeared after the first world oil crisis (1973). KraftJ and KraftA (1978) carried out pioneering work. They used the annual US data of 1947-1974 years to analyse and find that there was a one-way causality between GNP and energy consumption. Since then, many scholars have done many researches on different countries and regions by using a variety of analytical methods. Hossein and others used co-integration and error correction modeling technology to study the causality between the energy consumption and economic growth of OPEC countries, and added the environmental pollution factors to the economic growth model by increasing the carbon dioxide emissions caused by economic growth. They believed that a lot of energy consumption was unlikely to bring significant economic growth, but would lead to an increase in carbon dioxide emissions (Hossein, et al., 2012). Zhang used semi parametric panel data addition model to study the impact of coal, electricity and oil consumption on regional economic growth. The results show that the direction and intensity of coal, electricity and oil consumption on GDP are different in eastern, central and Western China. They are determined by combinations of linear and nonlinear effects (Zhang, 2012). Li and Zheng held that energy was one of the most basic materials in the national economy and played an important role in national production and life. Since the energy crisis in the 70s of last century, the relationship between energy consumption and economic growth has always been a matter of concern. Li and Zheng studied and analyzed the relationship between energy consumption and economic development based on the 1990 China time series 2009 VAR model, and then used impulse response function and variance decomposition to describe the correlation between economic growth and energy consumption. The results show that there is a one-way causality between energy consumption and GDP, and energy consumption has an obvious promoting effect on economic development (Li and Zheng, 2012). Shahbaz et al. used the autoregressive distribution lag (ARDL) model and the rolling window approach (RWA) to co-integrate the energy consumption and economic growth of Pakistan. Causality analysis used VECM Granger causality and innovative accounting methods, and causality analysis showed the feedback effect between economic growth and renewable energy consumption (Shahbaz et al., 2015). Herrerias and others studied the relationship between energy consumption and economic growth in China from 1995 to 2009. They believed that most of the previous studies ignored regional and cross sectional dependence in the provinces, and the impact of different energy policies on energy intensity by the government improved over time in 1990s and deteriorated from 2000. Therefore, it is necessary to examine these two periods, respectively. In addition, the breakdown of total energy consumption into electricity, coal, coke and crude oil consumption and its relationship with economic growth can provide new ideas for the design of energy policy in China. They used panel technology to test the long-term and short-term operational directions of these different types of energy consumption and economic growth, and proposed suggestions to adopt energy conservation policies without interruption of the growth path (Herrerias et al., 2013).

The study done by the above scholars has provided valuable conclusions for the understanding of the relationship between energy consumption and economic growth. From the current research on the relationship between energy consumption and economic growth, it can be found that there are still several aspects to be improved: firstly, the economic development is not equal in China, and the analysis of energy consumption and economic development in these areas is not deep enough; secondly, the analysis of the impact of energy consumption on economic development is less; thirdly, the comprehensive analysis of impact of diesel, gasoline, electricity and coal four energy sources on the economic growth is less. The gradient of China's regional economic development is more obvious, and there are great differences in the supply and consumption of energy. For the energy supply provinces, their energy consumption is different from that of the energy receiving provinces. The time series of national energy consumption and economic growth can be grasped in general, but the panel data in various provinces are used, especially the impulse response function method and the variance decomposition can be more precisely and profoundly analyzed. In view of this, the paper uses the method of panel data vector auto-regression (PVAR) to analyze the impact of China's economic development, coal, diesel, gasoline and electric power on each other.

3. Methods

3.1 PVAR model

A pioneering work in the research of the PVAR model is carried out and the problem of establishing VAR on the panel data is proposed, but in the equation model, a very strong hypothesis is set up to avoid limiting the lag length by assuming that the first phase of the observation is equivalent to the life of the first individual unit. That is, the corresponding relationship between the m length of the lag period and the period t is m (t) =t-1, but in fact, it is often difficult to observe the whole life of each economic unit, so this requires some assumptions based on the existing observation data to determine the relationship between the time series Z and y. In this paper, the fixed effect PVAR (1) model with a common deterministic event trend is studied, and random effect PVAR (1) model, fixed effect PVAR (/m) model and random effect PVAR (m) model are discussed. At the same time, the conclusion of PVAR (1) model can be easily deduced and can be applied to PVAR (m) model.
The PVAR model is to estimate the parameters of the model on the panel data, so it is not only a problem that needs to be seriously considered, but also the assurance of the robustness and credibility of the model establishment for how to choose the appropriate delay order, the interpretation of the impulse response map, the selection of exogenous and endogenous variables, and how to avoid the individual effect. As for the selection of lag order number P, some scholars have adopted the AIC and SIC criteria to judge, but an obvious question is how AIC and SIC are derived from it, and the reason is that the PVAR model does not take into account the two indicators. Other scholars have proposed the selection of P value based on the impulse response function, Schwartz information criterion and Akaike information criterion.

3.2 Economic growth and energy consumption theory

With regard to the theoretical research on the relationship between energy consumption and economic growth, when studying the US power industry, some scholars found that the relationship between power input and economic growth can be studied by the following formula:

$$Y = AK^{\alpha}E^{\gamma}L^{\beta}$$

In addition, the elasticity coefficient theory can better reflect the relationship between them. First, the concept of production function is introduced, and then the theory is explained on the basis of production function. A production function is a mathematical expression of the relationship between the amount of production factors invested in production and the output of these production factors. The so-called income elasticity of energy demand refers to the sensitivity of the change of energy demand to the change of income and reflects the change of income to energy demand. In studying the change of income, it can be carried out from two aspects of micro angle and macro angle. The micro angle means the individual residents and the macro angle represents the whole society, a country or the whole world. First, the situation of individual residents is analyzed, and then it is expanded to the whole country in order to analyze the influence of the change of income and national income on the energy demand from a theoretical point of view. As for the micro individual angle, under the hypothesis of rational economy and a certain level of income, the number of consumers to buy any consumer goods combination is necessarily the utility of the group to maximize its own. (The portfolio equilibrium diagram of commodity demand is shown in Figure. 1)

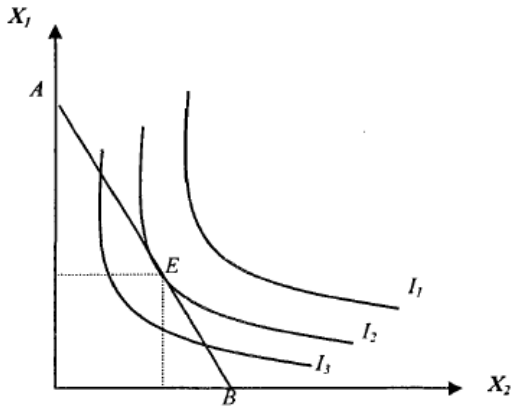

Figure 1: Portfolio equilibrium diagram of commodity demand

The combination of the energy model and the economic model into an overall model is an energy economic model. Energy and economic activities are closely related and interrelated. What energy system can be used to make reasonable use of funds to meet people's living standards and continuously improve their energy consumption needs is the most important issue in the energy system planning. Therefore, it is necessary to consider the energy model in the whole economic activities. However, the model is very complex and huge, and large energy economy models are often divided into several small models. Moreover, they are interrelated and relatively independent, so it is easy to calculate and analyze the result of calculation. The large energy economic model mainly includes the following small models: the economic development model, the energy demand model, the energy supply model, the energy economic impact model. (The schematic diagram of an economic model of energy is shown in Figure. 2)

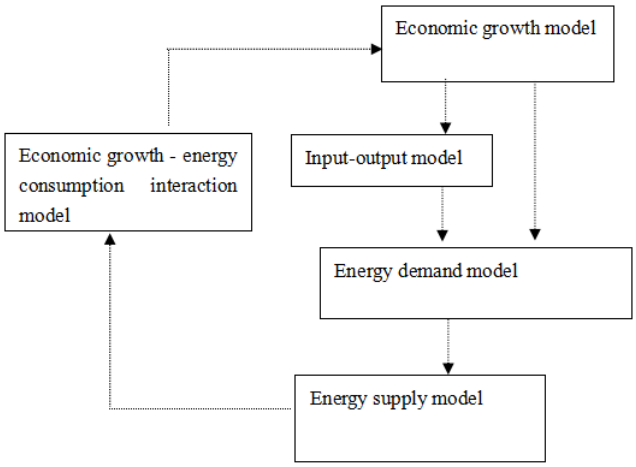

Figure 2: Schematic diagram of an economic model of energy

3.3 An empirical study based on static panel data model

In order to avoid the "false regression problem" in the panel data model estimation and to ensure the effectiveness of the estimated results, the smoothness of each panel data must be tested. The most common way to test data stationarity is unit root test. Five unit root test methods are adopted: LLC test, IPS test, Breitung test, FisherADF, PP test, and Hadri test. The unit root test is carried out for the level value or the first-order difference of lngdp, Inect, Incc, Ingc, Lndc and lnpc. The first-order difference is recorded as d (.), and the test results are shown in Table 1.

Table 1: Unit root test of panel data

Inspection methods	dlngdp	Inect	Incc	dIngc	lndc	lnpc
LLC	-9.61197	-10.7734	-6.45160	-14.8489	-6.74440	-6.41799
Breitung	-4.4244	2.3412	2.90626	5.65254	0.21362	2.28433
IPS	-4.16407	-4.54385	-2.27011	-7.82449	-1.36934	-1.98092
FisherADF	115.427	111.91	90.8252	158.481	83.4886	85.2413
PP	170.059	94.229	79.2778	205.320	83.1451	156.769

Table 2: Random effect test of fixed effect

Effect test method	Statistical quantity	Degrees of freedom	P values
Cross section F	23.723	(28，318)	0.000
Hausman	338.620	1	0.000

The identification of static panel data model is to identify the kind of model in the mixed model, the fixed effect model and the random effect model. The fixed effect model and the random effect model also have time effect, individual effect, individual and time double effect model. Moreover, it needs to analyze the model of that effect one by one. (Random effect test of fixed effect is shown in Table 2)

4. Results and discussion

4.1 Conclusions of static panel data model

On the whole, the elasticity of energy consumption to economic growth is divided into greater than 0, less than 0.1, and greater than 0.1. In 28 provinces and cities, Beijing's elasticity did not pass the T test. The T statistics of the other provinces and cities are both significant and greater than 0 in the significant level of 1%, indicating that energy consumption has a positive effect on the fluctuation of economic growth. For different regions, there is a difference between energy consumption and economic growth. Because of the different economic structure and development situation of different provinces and cities, it shows more complex spatial distribution characteristics. From the regression results, it can be seen that the whole model is well fitted and the estimated value of T statistics is significant under the significant level of 5%. Statistical significance shows that the change of energy consumption elasticity can explain the change of elastic fluctuation of economic growth better. The greater the value of the estimated model is, the greater the elasticity of energy consumption to economic growth is, and the greater the corresponding economic growth is. (Part of vi estimation results are shown in Table 3)

Table 3: Part of the results of the evaluation

Provinces and cities	v_i
Beijing	1.120
Tianjin	-0.120
Hebei	0.059
Shanxi	-0.052
Inner Mongolia	0.097
Liaoning	-0.351
Jilin	-0.342

Hausman and likelihood ratio tests are further used to determine the fixed effect model or the random effect model, and the results are shown in Table 4.

Table 4: Random effect test of fixed effect

Effect test method	Statistical quantity	Degrees of freedom	P values
Cross section F	20.3554	(28，315)	0.000
Hausman	282.669	4	0.000

From the table, it is known that the assumption of random effects is rejected under the 1% confidence level. That is to say, the introduction of a fixed effect model is more appropriate. Therefore, based on the results of F and Hausman tests, we establish a variable coefficient fixed effect model.

4.2 Software implementation of PVAR model estimation

The software used in this paper is StatalO.O and Eveiws6.0. The emphasis will be on StatalO.O. The Stata software is developed by the US computer resource center. From 1985 to 2012, a number of editions have been launched continuously. The latest version is Statal2.0. As the software is user-friendly and open, it has been welcomed by many scientific research institutions and institutions of higher learning. At the same time, people can edit the program they need conveniently according to the programming function it provides. Dr. Inessa Love of the World Bank provided the estimation package -pvar.ado of the PVAR model, and these programs can be easily obtained from the Internet. In terms of the choice of variable time in empirical analysis, according to the recognition condition of the PVAR model $T \geq 22m+3$, it is known that when the lag period is 1, the time length we select should satisfy $T \geq 25$, that is to say, at least 5 years should be chosen to establish the model. When the lag period is 2, the corresponding time length should satisfy $T \geq 27$, and when the lag period is 3, and then $T \geq 29$. Significance test is an effective way to test whether the regression coefficient is significant. Therefore, it is necessary to take into account the T statistic value of regression coefficient in different lag models, and whether it is significant under the significance of 1% or 5% in order to choose a better model. The impulse response function and the equation decomposition are the favorable tools to explain the results of the model. In the process of model interpretation, it should also consider whether the impulse response function diagram is convergent. If it is divergent, the unit root is not entirely in the unit circle and the model established is also unstable. In addition, the results of variance decomposition should be judged accordingly.

5. Conclusions

In the development of economic theory, many problems need to be analyzed by models. With the development of the world economy, the demand for energy is increasing. More and more scholars have begun to pay attention to the relationship between them and carry out research and analysis. In this paper, the PVAR model is used to identify relevant parameters. Based on the data of economic growth and energy consumption in the region, a practical study is conducted to explore the long and short term relationship between them. It is found that there is a certain discrepancy between economic energy consumption and energy consumption among different regions, and the spatial distribution is relatively complex. Economic growth may be affected by the total consumption of energy, and the impact of single energy consumption on economic growth is relatively small. Combined with the study, it can be known that the relationship between energy consumption and economic growth is relatively complex. In this paper, the relationship between the two is simply understood, the impact of economic growth and energy consumption still needs to be studied, and this is the focus of the future research.

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