

Research on Electricity Consumption and Economic Growth Based on Variable Coefficient Panel Data Regression

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Abstract—With the rapid economic development, China has become the largest power consumer, An accurate grasp of the relationship between electricity consumption and economic growth, the sustainable development of the economy and the development of electric energy policy will have a great help. This paper adopts the variable coefficient panel data model, on the base of panel data of electricity consumption and economic growth in 30 provinces in China from 1995 to 2013, panel unit root test and panel cointegration test are carried out. Then the model test is carried out. Combined with the results of the analysis of China's various regions of the relationship between power consumption and economic growth, the results show that the power consumption in China has a great influence on electricity consumption in the central region and a relatively small trend in the eastern and western regions. In terms of the level of economic development, the degree of influence of the developed and underdeveloped areas is also different. And put forward corresponding countermeasures to the results, which provides a strong basis for the establishment of energy-saving society in China. Innovation is the use of variable coefficient panel model can effectively analyze the impact of electricity consumption on the size of economic growth.

Keywords—Variable coefficient; Panel data; Economic growth; Electricity consumption

I. INTRODUCTION

The data used for theoretical model and case study are mostly cross-section data. Time series data, mixed section data, panel data. Although the time data and section data are one-dimensional data and the cross-section data are two-dimensional data, the observation object is unfixed. Panel data is two-dimensional data and the observation object is fixed, so panel data has become a hotspot for many modern scholars' research. The panel data has the following advantages, for example, reducing the possibility of collinearity of variables, increasing the degree of freedom, making the individual difference much easier to control, and improving the validity of the analysis result. The variable coefficient panel data model has a good economic explanation and can be used to explain the different cross sections of different time series. The

application of variable coefficient panel data in power consumption makes us better understand the relationship between power consumption and economic growth of the relationship and it has a great significance between the establishments of energy-saving society in China.

II. THEORETICAL BASIS

A. Panel unit root test

Panel data smoothness test is a necessary prerequisite for the study panel data, and now panel data model or analysis methods usually only be used in a smooth panel sequence. For the non-stationary panel data sequence, the units Root test must be carried out firstly. The unit root test of panel data is developed on the basis of unit root test of time series. In this paper, there are many the panel root test methods such as LLC [1]test, IPS [2]test and Fisher-ADF test, Fisher- PP[3] test

B. Panel cointegration test

Sometimes there may not be any linear relationship between the variables in the general linear regression model, but I found the parameter estimation statistic is significant when I do the regression analysis, this phenomenon is called pseudo-regression. If we are doing the Panel cointegration test using the Nonstationary panel data directly, the pseudo-regression may be taken place. Panel cointegration test can test whether there is cointegration relationship between variables. In order to avoid the "pseudo-regression" phenomenon occurred, we often use the Panel co-integration test methods, for example, Kao [4] test and Pedroni [5] test.

Kao test: Kao studied and proposed cointegration tests for homogeneous panel data in 1999, and the model was set up as follows:

$$y_{it} = \alpha_i + \beta x_{it} + \varepsilon_{it}, i = 1, \dots, N; t = 1, \dots, T \quad (1)$$

Based on Engle and Granger's proposed two-step method, Kao proposed the panel co-integration test based on DF and ADF. The test model is as follows:

$$\hat{\varepsilon}_i = \rho \hat{\varepsilon}_{i-1} + v_{it} \quad (2)$$

$$\hat{\varepsilon}_{it} = \rho \hat{\varepsilon}_{it-1} - \sum_{j=1}^p \varphi_j \Delta \hat{\varepsilon}_{it-j} + v_{it} \quad (3)$$

Pedroni[6]test: The Pedroni test takes into account the problem of panel heterogeneity, allowing unequal panel data and differences in benefit between individuals, which greatly relaxes the condition, testing the null hypothesis, and the alternative hypothesis[7]. The test model is as follows:

$$y_{it} = \alpha_i + \delta_{it} + \beta_i x_{it} + \varepsilon_{it}, i=1, \dots, N; t=1, \dots, T \quad (4)$$

$$\varepsilon = \rho_i \varepsilon_{it-1} + v_{it} \quad (5)$$

C. Variable Coefficient Panel Data Model Panel

The expression of the variable coefficient[8]panel data model is:

$$Y_{it} = X_{it} \beta_i + \mu_{it}, i=1, 2, \dots, n; t=1, \dots, T \quad (6)$$

Among X_{it} is $1 \times K$ vector, β_i is $K \times 1$ vector, K is the number of explanatory variables. Error term is μ_{it} , it can also be written

$$Y_i = X_i + u_i, i=1, 2, \dots, n \quad (7)$$

$$Y_i = \begin{pmatrix} Y_{i1} \\ Y_{i2} \\ \vdots \\ Y_{iT} \end{pmatrix}_{T \times 1}, X_i = \begin{pmatrix} X_{i11} & X_{i21} & \dots & X_{iK1} \\ X_{i12} & X_{i22} & \dots & X_{iK2} \\ \vdots & \vdots & \ddots & \vdots \\ X_{iT1} & X_{iT2} & \dots & X_{iT,K} \end{pmatrix}_{T \times K}, \beta_i = \begin{pmatrix} \beta_{i1} \\ \beta_{i2} \\ \vdots \\ \beta_{iK} \end{pmatrix}_{K \times 1}, \mu_i = \begin{pmatrix} \mu_{i1} \\ \mu_{i2} \\ \vdots \\ \mu_{iT} \end{pmatrix}_{T \times 1} \quad (8)$$

The intercept of the model is denoted by β_{i1} , while the first column of all elements in X_i is 1. The number of explanatory variables for the model is $(K-1)$. That is, the intercept is treated as a coefficient of the dummy variable whose observation is 1. The model first uses a least-squares method to compute $\hat{\beta}_i = (X_i' X_i)^{-1} X_i' Y_i$ and its residual $\hat{\mu}_i = Y_i - X_i \hat{\beta}_i$ and thus obtain unbiased estimates of δ_i^2 and Δ .

$$\hat{\delta}_i^2 = \frac{\hat{\mu}_i' \hat{\mu}_i}{T-K} = \frac{1}{T-K} Y_i' (I - X_i (X_i' X_i)^{-1} X_i') Y_i \quad (9)$$

$$\hat{\Delta} = \frac{1}{n-1} \sum_{i=1}^n (\hat{\beta}_i - n^{-1} \sum_{j=1}^n \hat{\beta}_j) (\hat{\beta}_i - n^{-1} \sum_{j=1}^n \hat{\beta}_j)' - \frac{1}{n} \sum_{i=1}^n \hat{\delta}_i^2 (X_i' X_i)^{-1} \quad (10)$$

The results of GLS (Generalized Least Squares) [9] of the best linear unbiased estimator of β are as follows:

$$\hat{\beta}_{GLS} = \left[\sum_{i=1}^n X_i' \Phi_i^{-1} X_i \right]^{-1} \left[\sum_{i=1}^n X_i' \Phi_i^{-1} Y_i \right] = \sum_{i=1}^n W_i \hat{\beta}_i \quad (11)$$

in the formula

$$W_i = \left\{ \sum_{i=1}^n [\Delta + \delta_i^2 (X_i' X_i)^{-1}]^{-1} \right\}^{-1} [\Delta + \delta_i^2 (X_i' X_i)^{-1}]^{-1} \quad (12)$$

III. ANALYSIS OF ELECTRICITY CONSUMPTION AND ECONOMIC GROWTH

Based on the panel data of provinces and cities in China, this paper studies the relationship between power consumption and economic growth in China. The panel data collected by China's 30 provinces (due to incomplete data in Xizang, were excluded). Real GDP data and electricity consumption data for the year 1995 to 2013. All data are from the National Bureau of Statistics

A. Panel unit root test

First of all, the data of the panel unit root test, the methods used are LLC test, IPS test, and Fisher-ADF test, Fisher-PP test. To check whether the sequence is a stationary sequence, the results are shown in figure:

TABLE I. PANEL UNIT ROOT TEST OF LNGDP AND LNPOWER

Variable	lnGDP	Statistical p-values	lnpower	Statistical p-values
LLC test	6.1893	1.000	4.4567	1.000
IPS test	12.836	1.000	11.386	1.000
ADF test	6.4642	1.000	7.5629	1.000
PP test	6.6781	1.000	5.5143	1.000

From the above test results, power consumption and economic growth of unit root test results did not reject the "existence unit root" of the original hypothesis, so the data is non-stationary data, it can not be directly regression. The data needs to be differentiated.

TABLE II. UNIT ROOT AFTER FIRST ORDER DIFFERENCE

Variable	Δ lnGDP	Statistical p-values	Δ lnpower	Statistical p-values
LLC test	-6.9204	0.002	-13.4355	0.000
IPS test	-5.3539	0.000	-10.7640	0.000
ADF test	122.31	0.007	230.202	0.000
PP test	141.17	0.000	208.670	0.000

It can be seen from the above table that the first order difference of power consumption and economic growth all reject the existence unit root at the significant level of 1%, so all are stationary series. In other words, economic growth and electricity consumption are first-order single-sequence. As a whole sequence, so we can further cointegration test method to determine whether there is a long-term equilibrium relationship between electricity consumption and economic growth.

B. Panel cointegration test for electricity consumption and economic growth

Sometimes, although the two variables are non-stationary (such as random walk process), but they are a linear combination may be smooth. In this case, the two variables are said to be cointegrated. Many of the time series data in the economy are not stable, but they may be affected by some common factors, thus showing a common trend in time, that is, there is a stable relationship between variables, their changes are affected by this. So that some linear combination of them may be stable, that is, there is a cointegration relationship between them.

From the panel root test results, power consumption and economic growth are first-order single-sequence, panel unit root test is based on a single sequence, and the front panel unit root test has a very good solution to this problem. Kao test and Pedroni test results are as follows:

TABLE III. THE RESULTS PANEL COINTEGRATION PEDRONI TEST RESULTS

Testing Method	Test Hypothesis	Statistic Name	Statistical Value	Statistical P-values
PEDRONI TEST	$H_0: \rho=1$ $H_1: (\rho < 1)$	PANEL V-STATISTIC	3.7663	0.0001
		PANEL RHO-STATISTIC	-2.6772	0.0037
		PANEL PP-STATISTIC	-4.2324	0.0000
		PANEL ADF-STATISTIC	-5.4301	0.0000
		GROUPRHO-STATISTIC	-0.7291	0.0330
		GROUPPP-STATISTIC	-4.6147	0.0000
		GROUPADF-STATISTIC	-3.4301	0.0003

TABLE IV. THE RESULTS FOR PANEL COINTEGRATION KAO TEST

Testing Method	Test Hypotheses	Statistic Name	Statistical value	Statistical P-values
KAO test	$H_0: \rho=1$	ADF	-6.7876	0.0000

From the above two test methods, we can see that, at the significance level of 5%, the test results reject the null hypothesis that there is a panel cointegration relationship between electricity consumption and economic growth. This makes sense for the model regression laboratory we will follow.

C. Variable Coefficient Panel Data Model Regression

Taking the total economic consumption of each province as the explanatory variable and the electricity consumption of each province as the explanatory variable, the panel data are used as the sample data because there is a certain gap between the electricity consumption and the economic growth in China. We selected 30 provinces in Hebei, Henan, Heilongjiang, Hubei, Hunan, Jilin, Jiangsu, Jiangxi, Liaoning, Inner Mongolia, Qinghai, Shandong, Shanxi, Shaanxi, Shanghai, Sichuan, Tianjin, Yunnan, Zhejiang. The data is Electricity consumption and economic growth data from 1995-2013 (Note: the data from the China Statistical Yearbook). Using the model to set the test method, we first need to get the sum of squares of

residuals estimated by each model, and the results of each calculation are shown in the following table:

TABLE V. THE SUM OF SQUARES OF RESIDUALS FOR EACH MODEL

	Variable Coefficient Model S1	Variable Intercept Model S2	Mixed Regression Model S3
Residual sum of squares	2.990351	13.61021	68.58442

Based on the sum of squares of residuals, the values of F_2 and F_1 can be calculated and given a significance level $\alpha=0.05$, the following can be calculated:

$$F_2 = \frac{(S_3 - S_1) / [(n-1)(K+1)]}{S_1 / [nT - n(K+1)]} = 17.80 \quad (13)$$

$$F_1 = \frac{(S_2 - S_1) / [(n-1)K]}{S_1 / [nT - n(K+1)]} = 57.31 \quad (14)$$

Check the F distribution table, given the significance level of 5%, you can get the critical value:

$$F_1(29, 510) = 1.36 \quad (15)$$

$$F_2(58, 510) = 1.26 \quad (16)$$

Observe the above calculation results can be seen, F_2 statistics is greater than its critical value of 1.26, so the need to reject hypothesis 2, then we need to test the model coefficients and intercept will change with the individual good time, Since the statistics of F_1 is larger than its critical value of 1.36, we need to reject hypothesis 1. Therefore, the model should choose to adopt the variable coefficient panel model, Specific forms:

$$GDP_{it} = \alpha_i + \beta_i \text{Power}_{it} + u_{it}, \quad i=1,2,\dots,N, t=1,2,\dots,T \quad (17)$$

TABLE VI. ESTIMATION RESULTS OF VARIABLE COEFFICIENT PANEL MODEL (EASTERN REGION)

East Region			
Province	Coefficient	T statistic	Statistical P-values
LiaoNing	1.8145	33.6142	0.000
HeBei	1.2369	50.5276	0.000
ShangDong	1.3014	41.1025	0.000
JiangSu	1.1523	38.8040	0.001
ZheJiang	1.0790	37.2072	0.000
FuJian	0.8249	31.7633	0.020
GuangDong	0.9764	64.0791	0.000
BeiJing	1.6793	31.1033	0.000
TianJin	1.7171	41.3547	0.000
ShangHai	1.6015	49.6459	0.000
HaiNan	0.7509	36.3293	0.000
average	1.2235		

TABLE VII. ESTIMATION RESULTS OF VARIABLE COEFFICIENT PANEL MODEL (CENTRAL REGION)

Central Region			
Province	Coefficient	T statistic	Statistical P-values
JiLin	2.4483	30.4874	0.000
HeiLongJiang	2.3727	35.5227	0.000
NeiMengGu	1.1288	39.1184	0.000
ShanXi	1.5034	36.1815	0.000
HeNan	1.3604	44.7776	0.000
AnHui	0.9064	34.5634	0.000
JiangXi	1.3521	33.1494	0.000
HuNan	1.5485	29.0958	0.000
HuBei	1.6548	48.7071	0.000
average	1.5862		

TABLE VIII. ESTIMATION RESULTS OF VARIABLE COEFFICIENT PANEL MODEL (WESTERN REGION)

Western Region.			
Province	Coefficient	T statistic	Statistical P-values
XinJiang	0.9880	25.2415	0.000
GanSu	1.0870	30.9179	0.001
ShanXi	1.6683	49.1999	0.000
NingXia	1.1682	28.4622	0.000
SiChuan	1.4910	16.1141	0.000
ChongQing	1.3277	12.1317	0.000
GuiZhou	1.0984	49.5948	0.000
YunNan	1.1030	41.0770	0.000
GuangXi	0.9706	73.6328	0.003
QingHai	1.1304	48.6907	0.000
average	1.2033		

The results show that China's power consumption plays an important role in promoting economic growth; the extent of influence of power consumption on economic growth is different in different regions. Generally speaking, the influence of electricity consumption in central area is larger, the eastern part is weaker and the western area is less. From economic development level, , The developed regions and the less developed regions of the impact of the gap is also large, which may be China's population base, economic structure and the wide application of new energy, Therefore, we can not formulate a unified national electricity consumption programs, we need to develop according to the different regions of each region and economic growth dependence on the size of

electricity consumption to develop the appropriate power consumption policy, In order to achieve the optimal allocation of power resources for the establishment of energy-saving society in China has provided help.

IV. CONCLUSION

According to the data of electricity consumption and economic growth in China, the unit power root test and panel cointegration test show that the data of electricity consumption and economic growth in China are first-order single integers, and there exists cointegration relationship between them. The results show that the electricity consumption in China has a great influence on electricity consumption in the central region and a relatively small trend in the eastern and western regions. From the economic development level, the developed regions And the extent of the impact of underdeveloped areas are also different. And different provinces and autonomous regions of the power consumption elasticity is also different, the rapid development of coastal cities rely heavily on electricity consumption. The data model of variable coefficient panel is used to analyze the extent of influence of power consumption on economic growth in various regions of China. It provides a good basis for the power sector to formulate power resource optimization program.

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