An Empirical Research on Characteristics of Coal Consumption Based on Panel Co-Integration

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Abstract This paper constructs a panel coal consumption model and defines the panel data for coal consumption and growth as well as coal efficiency for 36 major sectors of Chinese industry during1993-2007. Applying the panel unit root W test by IPS, The anthor concluds that the panel data is generated by the panel unit root process. This paper tests panel co-integration among three panel variables by Pedroni residual co-integration test and estimates the model with FMOLS proposed by Philips and Hansen. The results show that there is a panel co-integration relationship among the three panel variables which characterizes the coal consumption of the 36 major sectors of Chinese industry. The conclusions and their implications in this paper can be taken as reference evidence for formulating a long-run energy strategy for China. It has important significance for China to reduce coal consumption, control greenhouse gas emissions and achieve sustainable development.
Key words Coal consumption; Coal efficiency; Industry growth; Panel co-integration

1 Introduction

Chinese economic growth depends highly on energy consumption. During 2003-2005, Chinese elasticity ratio of energy consumption respectively reached 1.53, 1.59 and 1.02, bigger than 1 continuously, in 2004 reached as high as 1.59. Chinese ‘Eleventh Five-Year Plan’ (2006-2010) clearly states: to develop vigorously cyclic economy, accelerate the construction of a resource-conserving, environment-friendly society, promote economic development in coordination with population, resources and the environment. After ‘Eleventh Five-Year Plan’, Chinese elasticity ratio of energy consumption was down quickly back to 0.83, 0.60 and 0.44 respectively in 2006, 2007 and 2008. Chinese energy structure dominated by coal, coal consumption accounts for about 70% of total energy consumption. With increasing of Chinese GDP, coal consumption has also increased year by year. It reached 195,709.5 million tons of standard coal in 2008, which was 6.03 percent more than the coal consumption in 2007, and was nearly 5 times the coal consumption in 1978. The pattern of economic growth of China is still extensive. Utilization efficiency of energy resources is low. Energy demand will continue to grow. Controlling greenhouse gas emissions face intense pressure and the special difficulties. All those above are major constraints in achieving sustainable development of China.

In the industrial structure, industrial energy consumption takes a large proportion of total energy consumption, exceeding its proportion of GDP. In 2007, Chinese industry occupied 43.0% of GDP, but its energy consumption occupied 71.60% of total energy consumption, and its coal consumption occupied 94.83% of total coal consumption. This paper constructs the panel co-integration coal consumption model, and analyses the specific characteristics of the coal consumption of the major sectors of Chinese industry in the long-run, and its conclusions can be taken as reference evidence for formulating a long-run energy strategy for China. Specifically, we construct the panel data of three panel variables which are coal consumption, growth and coal efficiency of 36 major sectors of Chinese industry. We will test whether there is panel co-integration among three panel variables and estimates the panel model to reveal the characteristics of the growth of various sectors depending on coal consumption. This has the vital practical significance for our adjusting the industrial structure and formulating a long-run energy strategy for China. This has important significance for China to reduce coal consumption, control greenhouse gas emissions and achieve sustainable development.

In the existing literature the massive research mainly focused on using the standard co-integration theory to examine whether there is a relationship between energy consumption and GDP for the long-term equilibrium or causality. Cheng (1996) applied the standard unit root test and co-integration test to examine whether there is a relation between Indian energy consumption and GDP for the long-term equilibrium and short-term adjustment. Chang Youngho and Jiang Chan (2003) used granger causality tests to examine the influence caused by the fluctuation of the oil price on Chinese economic growth. Wang Shaoping, Yang Jisheng [1](2005) use longitudinal co-integration model analyze the relationship between growth of 12 major Chinese industrial sectors and their energy consumption in the long-term and the short-term.

2 The Model

Chinese industrial sectors growth obviously depend on the high energy consumption, and low energy efficiency should be the main reason why the Chinese industrial energy consumption is so high. It is necessary for Chinese industrial coal consumption model to introduce coal efficiency variable (i.e. the output value of per coal consumption). This paper selects the panel data of coal consumption, gross output value and coal efficiency of 36 major sectors of Chinese industry during 1993-2007 as a sample to study. Among them, the units of coal consumption are million tons. Because there's no gross output value of total industrial enterprises by industrial sector, we use the data of all state-owned and non-state-owned above designed size industrial enterprises by industrial sector instead. The gross output value of 36 major industrial sectors in current prices were converted to 1993 output value at constant price according to ex-factory price indices of industrial products by sector.

Letting Y_{it} and X_{it} represent respectively coal consumption (unit: 10000 tons) and real gross output value (output value at constant price in1993, unit: billion yuan) of the isector and the ttime. Letting z_{it} represent coal efficiency (unit: billion yuan /10000 tons) of the same sector and same time. The panel model of major sectors of Chinese industry coal consumption is:

$$Y_{it} = X^{\beta_{1i}}{}_{it} e^{(\alpha_i + \beta_{2i} z_{it} + u_{it})} \qquad i = 1,\ldots,36,\ t = 1,\ldots,15 \tag{1}$$

There, β_{1i} measures elasticity ratio of coal consumption of the sector *i*, α_i measures industrial sector *i* static dependence on coal, which determined by the nature of the industrial sector, β_{2i} reflects the dynamic change of the coal efficiency on sector growth of the industry, u_{it} reflects other factors influencing on the coal consumption of the *i* industrial sector in the *t* time. Letting $y_{it} = \log(Y_{it})$, $x_{it} = \log(X_{it})$, then model (1) can represent as following:

$$y_{it} = \alpha_i + \beta_{1i} x_{it} + \beta_{2i} z_{it} + u_{it} \qquad \text{i} = 1,\ldots,36,\ \text{t} = 1,\ldots,15 \tag{2}$$

Since α_i, β_{1i} and β_{2i} are determined by industrial characteristics, and characteristics of coal consumption of various sectors may be different, the panel data model (2) has the heterogeneity, the model parameters for different industrial sectors may not be the same.

3 Estimation and Test

3.1 Panel unit root test

In order to test the panel co-integration model (2) and to estimate the panel co-integration vectors, we should do panel unit root tests for model variables y_{it}, x_{it} and z_{it} first.

Panel unit root test refers to take all cross-section series of panel variable as a whole to take unit root test, this paper use Im, Persaran and Shin W-statistic[2] (Bai Zhonglin,2008) to achieve panel unit root test, the idea is a longitudinal section time series (such as y_{it}) regression using ADF test

$$\Delta y_{it} = \alpha_i + \beta_i y_{i,t-1} + \sum_{j=1}^{p_i} \phi_{ij} \Delta y_{i,t-j} + \varepsilon_{it}, \tag{3}$$

$$H_0 : \beta_i = 0 \ (i = 1,2,\cdots,N)$$

$$H_1 : \beta_i < 0 \ (i = 1,2,\cdots,N_1),\ \ \beta_i = 0 \ (i = N_1 + 1, N_1 + 2,\cdots,N)$$

Table 1 displays the results of panel unit root W_{IPS} tests. In the table 1, all left side p-values of panel variable y_{it}, x_{it} and z_{it}' W_{IPS} test for level values are more than 0.7, we can not reject H_0.And all left side p-values of panel variable y_{it}, x_{it} and z_{it}' W_{IPS} test for the first difference values are less than 0.007,we should reject H_0 at 0.5% level. Therefore, three variables y_{it}, x_{it} and z_{it} are panel I (1) generated by the process. This conclusion shows not only the non-stationary feature of the major sectors of Chinese industrial growth, coal consumption and coal efficiency, but also the base of the following panel data co-integration test and estimation .

Table 1 Results of Panel Unit Root W_{IPS} Tests

Variable		Statistic	Prob.	Variable	Statistic	Prob.
y_{it}	level	0.79891	0.7878	1st difference	-11.3695	0.0000
x_{it}	level	6.84144	1.0000	1st difference	-3.05211	0.0011
z_{it}	level	3.86408	0.9999	1st difference	-2.48627	0.0065

Exogenous variables: Individual effects, individual linear trends.
Automatic selection of maximum lags.
Automatic selection of lags based on SIC: 0 to 2.

3.2 Pedroni residual co-integration test

Using eviews6.0, we take Pedroni residual co-integration test for three panel variables: y_{it} , x_{it} and z_{it} , the results are shown in table 2.

Table 2 Pedroni Residual Co-integration Tests

Null Hypothesis: No co-integration					
Alternative hypothesis: common AR coefs. (within-dimension)			Alternative hypothesis: individual AR coefs. (between-dimension)		
Panel	Statistic	Prob.	Group	Statistic	Prob.
PP-Statistic	-6.233101	0.0000	PP-Statistic	-5.095148	0.0000
ADF-Statistic	-4.124945	0.0000	ADF-Statistic	-3.586711	0.0002

From table 2, in any situation we should reject null hypothesis: no co-integration, *i.t.* there are co-integration relationships among the three panel variables: y_{it} , x_{it} and z_{it} .

3.3 Fully modified OLS of panel co-integration vector

We estimates the model (2) with FMOLS proposed by Philips and Hansen [3] (1990) and by using MATLAB program, we get formula (4),and panel co-integration vectors β_{1i} and β_{2i} show in table 3.

$$y_{it} = \hat{\alpha}_i + \hat{\beta}_{1i} x_{it} + \hat{\beta}_{2i} z_{it} + \hat{u}_{it} \tag{4}$$

In table3, the industrial sector which has the highest elasticity ratio is leather, furs, down and related products whose elasticity ratio of coal is 1.8415, and other industrial sectors which have relatively higher elasticity ratio of coal are petroleum and natural gas extraction(1.3607), food manufacturing(1.3127), textile industry(1.3139), papermaking and paper products(1.1622), rubber products(1.3748), smelting and pressing of ferrous metals(1.1139) .These industrial sectors above growth depends on the high coal consumption. The industrial sectors which have negative elasticity ratio of coal are nonferrous metals mining and dressing, tobacco processing, furniture manufacturing, printing and record medium reproduction, cultural, educational and sports goods, medical and pharmaceutical products, metal products, equipment in common use, transport equipment, electric equipment and machinery, telecommunications equipment, computer and electronic equipment, Instruments, meters, cultural and office machinery. These industrial sectors above which have negative elasticity ratios of coal were because these sectors were increasing in output, while coal consumption declining. However, the total energy consumption were still increasing, these reduced coal consumption were replaced by other energy sources. The industrial sector which has the biggest coal efficiency coefficient is production and supply of electricity and heating power whose absolute value of coal efficiency coefficient is 16.844, and other industrial sectors which have relatively bigger absolute value of coal efficiency coefficient are papermaking and paper products(-1.9426), petroleum processing, coking and nuclear fuel processing(-5.5237), raw chemical materials and chemical products(-1.6667), nonmetal mineral products(-2.4545), smelting and pressing of ferrous metals(-1.9949), production and supply of gas(-2.8809). Increasing coal efficiency of those industrial sectors can reduce validly coal consumption.

Table 3 Results of Panel Co-integration Vectors

i	Industrial sector	β_{1i}	β_{2i}
1	coal mining and dressing	1.0660 (4.7116)	-8.3534(-2.664)
2	petroleum and natural gas extraction	1.3607(2.2347)	-0.4956 (-6.180)
3	ferrous metals mining and dressing	0.3637(1.6043)	-0.0523(-0.725)
4	nonferrous metals mining and dressing	-0.8026(-1.581)	0.0277 (0.3134)
5	nonmetal minerals mining and dressing	1.0505(3.4715)	-0.9693(-0.687)
6	non-staple food processing	0.0642(0.1419)	-0.0781(-0.687)
7	food manufacturing	1.3127(2.9277)	-0.7183 (-3.372)
8	beverage manufacturing	0.1215(0.1699)	-0.1402(-0.523)
9	tobacco processing	-0.3013(-0.693)	-0.0119(-0.428)
10	textile industry	1.3139(5.1501)	-0.4777 (-5.116)
11	garments, shoes and hats manufacturing	1.0678(4.3326)	-0.0756 (-3.103)
12	leather, furs, down and related products	1.8415 (4.0034)	-0.1155(-4.735)
13	timber processing, bamboo, cane palm fiber and straw products	0.3378(1.3971)	-0.0869(-1.159)
14	furniture manufacturing	-0.3169(-2.078)	-0.0014(-0.302)
15	papermaking and paper products	1.1622(3.8934)	-1.9426(-3.008)
16	printing and record medium reproduction	-0.5613(-2.089)	0.0029 (0.3134)
17	cultural, educational and sports goods	-0.2682 (-1.073)	-0.0049(-1.062)
18	petroleum processing, coking and nuclear fuel processing	1.0199 (7.0078)	-5.5237 (-3.254)
19	raw chemical materials and chemical products	1.0413(1.9871)	-1.6667(-1.818)
20	medical and pharmaceutical products	-0.8586 (-2.128)	0.2007 (1.1790)
21	chemical fiber	0.1080(0.2712)	-0.0749(-0.292)
22	rubber products	1.3748 (2.9876)	-0.4952(-3.379)
23	plastic products	0.8414(4.0401)	-0.0939 (-5.009)
24	nonmetal mineral products	0.9957(3.8354)	-2.4545 (-2.983)
25	smelting and pressing of ferrous metals	1.1139 (1.5521)	-1.9949(-1.128)
26	smelting and pressing of nonferrous metals	1.0123(2.6053)	-0.5783(-1.880)
27	metal products	-0.2101(-0.573)	-0.0054(-0.244)
28	equipment in common use	-1.1782(-3.602)	0.0368(0.3145)
29	special purpose equipment	1.0104(3.0532)	-0.1237(-3.450)
30	transport equipment	-0.2281(-1.052)	0.0126(0.7967)
31	electric equipment and machinery	-0.8874(-4.409)	0.0079(0.2954)
32	telecommunications equipment, computer and electronic equipment	-0.2280(-1.718)	0.0011(0.8688)
33	Instruments, meters, cultural and office machinery	-0.9229(-5.794)	0.0048(0.5781)
34	production and supply of electricity and heating power	0.9418(2.8368)	-16.844(-1.236)
35	production and supply of gas	0.5051(1.7132)	-2.8809(-1.000)
36	production and supply of water	0.9021(4.4418)	-0.1046(-4.436)

Note: *t* statistics for the coefficient estimators are in brackets

Our long-term energy (coal) strategy and structural adjustment should focus on those industrial sectors which have relatively higher elasticity ratio of coal and increasing coal efficiency has relatively low effect on reducing coal consumption, such as industrial sectors of petroleum and natural gas extraction, food manufacturing, textile industry, leather, furs, down and related products, rubber products and equipment in common use. We also should take coal-saving technological transformation to support those industrial sectors which increase in coal efficiency have relatively strong effect on reducing their coal consumption, such as industrial sectors of coal mining and dressing, papermaking and paper products, petroleum processing, coking and nuclear fuel processing, raw chemical materials and chemical products, nonmetal mineral products, smelting and pressing of ferrous metals, production and supply of electricity and heating power, production and supply of gas, in order to weaken coal dependence of the major sectors of Chinese industry and promote Chinese industrial structure upgrade.

4 Conclusions

Applying the panel unit root test and panel co-integration test, this paper tests and estimates the model of three panel variables which are coal consumption, growth and coal efficiency of 36 major sectors of Chinese industry to reveals the basic features of coal consumption of the major Chinese industrial sectors. The conclusions are: there are long-term equilibrium relationship among coal consumption, the growth of industrial sector and coal efficiency. Most sectors have positive elasticity ratio of coal, more than one-third of all sectors have high coal consumption and their growth strong depend on coal consumption. But less than one-third of all sectors have negative elasticity ratio of coal. It is because these sectors were increasing in output, while coal consumption declining. However, the total energy consumption were still increasing, these reduced coal consumption were replaced by other energy sources. The enhancement coal efficiency has significant effect on reducing coal consumption for most sectors.

Our long-term energy (coal) strategy and structural adjustment should focus on those industrial sectors which have relatively higher elasticity ratio of coal and increasing coal efficiency has relatively low effect on reducing coal consumption. We also should take coal-saving technological transformation to support those industrial sectors which increase in coal efficiency have relatively strong effect on reducing their coal consumption, in order to weaken coal dependence of the major sectors of Chinese industry and promote Chinese industrial structure upgrade.

Because there's no gross output value of total industrial enterprises by industrial sector, we use the data of all state-owned and non-state-owned above designed size industrial enterprises by industrial sector instead. Some elasticity ratio of coal consumption of industrial sector may be bigger than real one.

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