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Study on the relationships between coal consumption and economic growth of the six biggest coal consumption countries: with coal price as a third variable

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Abstract

Coal remains the world's most important energy resource and it reached the highest share of global primary energy consumption (29.9%) in 2012, which was the highest level since 1970 according to the statistics of the British Petroleum public limited company. As to the relationship between coal consumption and economic growth, many studies have been done and there have not been consistent results gained yet in previous research. To further explore the relationship and look for more reliable support for policy making in different countries, with coal price as a third variable, the panel data model using a common source of data from 2000 through 2010 is applied in this paper in the tests of unit root, panel cointegration and Granger causality among the six main coal consumption countries, namely China, the United States of America, India, Germany, Russia and Japan. The tests show: (1) Bidirectional causal relationships between coal consumption and economic growth exist in Germany, Russia and Japan. (2) Only a unidirectional causality from economic growth to coal consumption exists in China. (3) There are no causal relationships between coal consumption and economic growth in USA and India. These coincident results with previous research further indicate that each country should form their own coal consuming policies according to their own situations.

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Keywords: coal consumption; economic growth; coal price; panel data model; policy making

1. Introduction

1.1 Nonsubstituable role of coal

Coal remains the world's most important energy resource. Compared with other fossil fuel resources, coal resource is widely distributed in the world. According to the statistic data of the British Petroleum

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public limited company (BP) in 2013 [1], coal consumption reached 29.9 percent of global primary energy consumption in 2012, which was the highest level since 1970.

According to the data of the International Energy Agency (IEA) in 2012, China, the United States of America (USA), India, Germany, Russia and Japan were the top six biggest countries which consume the most coal throughout the world in 2010, accounting for 76 percent of world's coal consumption [2]. Coal resource probably will continue to play an important role in energy supply in the next several decades according to the present situation of energy reserves, as the proved reserve of coal was estimated to last 109 years while proved reserves of oil and natural gas were estimated to last only 52.9 years and 55.7 years respectively [1].

1.2 Relationship of coal consumption and economic growth

Kraft and Kraft first found economic growth had a positive impact on energy consumption in USA in 1978 [3]. Following them, a large number of experts studied the relationships between energy consumption and economic growth. Generally speaking, there are four main viewpoints.

The first viewpoint is that a unidirectional causal relationship exits from economic growth to energy consumption. For example, Yang, H.Y provided evidence of unidirectional causality from economic growth to coal consumption [4]. Matthew Bartleet, Rukmani Gounder examined the energy consumption-growth nexus in New Zealand from 1960 to 2004 and found the Granger causality from real GDP to energy consumption [5]. A.A. Azlina tested for the existence and direction of causality between energy consumption and economic development in Malaysia, and the results indicated that there was directional causality running from economic development to energy consumption [6]. M.J. Herrerias et al. investigated the relationship between energy and economic growth across Chinese regions from 1995 to 2009 and the results showed that there was unidirectional causation from economic growth to energy consumption in the long-run [7].

The second viewpoint recognizes that there is a unidirectional causal relationship from energy consumption to economic growth. Abosedra and Baghestani indicated unidirectional causality from output to energy consumption in USA from 1947 to 1987 [8]. Sari and Soytas found that coal consumption explained the cause of up to 8% of the forecast error variance in real GDP for Turkey [9]. Zhangwei Li, Xungang Zheng analyzed the relationship between energy consumption and economic development based on the vector autoregression (VAR) model using temporal series of China from 1990 to 2009 and got the results that there was a unidirectional causality from energy consumption to gross domestic product [10]. Djula Borozan made a study of the relationship between the two in Croatia covering the period between 1992 and 2010, employing the bivariate VAR and Granger causality tests. The result showed there was a unidirectional causality running from total energy consumption to GDP [11]. Yris D. Fondja Wandji studied the nature of the relationship between energy consumption and economic growth and the results revealed that a percentage point increase in oil products consumption could boost the economic growth by around 1.1% [12].

The third indicates that a bidirectional causality exits between the two variables. Yang [13] and Lee and Chang [14] proved bidirectional causality existed between coal consumption and economic growth. Seung-Hoon Yoo once proved that there was a bidirectional causality between the two in Korea [15]. Leila Dagher, Talar Yacoubian investigated the dynamic causal relationship between energy consumption and economic growth in Lebanon from 1980 to 2009 and found strong evidence of a bidirectional relationship both in the short-run and in the long-run [16]. Presley K. Wesseh Jr., Babette Zoumara conducted causal interdependence between energy consumption and economic growth in Liberia and got the result there was bidirectional causality between the two variables [17]. Hassan Mohammadi, Shahrokh Parvaresh used dynamic fixed effect, pooled and mean-group estimators to examine the long-run relation and short-run dynamics between energy consumption and output in a panel of 14 oil-exporting countries over 1980-2007, and proved bidirectional causality in both long and short run between the two [18].

The fourth opinion shows there is no causal relationship between energy consumption and economic growth, supported by some scholars such as Sadr, Seyed Mohammad Hossein, Gudarzi Farahani etc. [19] and Harry Bloch, Shuddhasattwa Rafiq, Ruhul Salim [20] and so on.

1.3 Research methods

With the advantages of the model itself compared with cross section data or time series data models, Panel data model can conduct more comprehensive economic analyses, solve the problem of insufficient samples, allow heterogeneity among different countries and avoid the problems of low degree association with the traditional unit root and cointegration test. So many empirical studies have employed the panel data model to study the relationship between energy consumption and economic growth in different countries or regions in different periods. Such as RenukaMahadevan, John Asafu-Adjaye [21], Bwo-Nung Huang [22], Chien-Chiang Lee, Yi-Bin Chiu [23], Ilhan Ozturk et al [24], Nicholas Apergis [25], Nicholas Apergis [26].

From the literature above, we may find that the most popular model used probably is panel data model using the data wherever available. The variables mostly concerned are energy consumption and economic growth. For this research, panel data model is chosen again based on the experience of previous research but with one more variable added in the model which is coal price as coal price influences both coal consumption and economic growth [27]. Meanwhile, we try to use the same caliber data of same time length to analyze the relationship between coal consumption and economic growth to provide more identical bases for comparison among different countries. The main purpose of this study is to further investigate whether there are regular patterns existing in causal relationship between coal consumption and economic growth in the six biggest coal consumption countries so as to provide more reliable bases for policy decisions in these countries.

2. Materials and Methods

2.1.Materials

We choose 2000 to 2010 as the common period for the study. The growth rates of coal consumption and economic growth are designed as the main variables with coal price as a third variable in this paper. The growth rate of coal consumption is represented by CC in kg of oil equivalent per capita. The economic growth is represented by the growth rate of GDP per capita (GDP). As comparable coal prices of the same periods aren't available, referring to the researches of Renuka Mahadevan and John Asafu-Adjaye [21], Nicholas M. Odhiambo [27], John Asafu-Adjaye [28], coal price is replaced by the consumer price index (CPI).

The data of CC are from BP statistical review of world energy June 2009 [29] and BP statistical review of world energy June 2011 [30]. GDP are from the data on per capita GDP (constant 2000 US$) of World Bank [31] [32]. CPI comes from U.S. Bureau of Labor Statistics [33], with 1982-84 as the base year. CC, GDP and CPI of the six countries are shown in Figure 1, Figure 2 andFigure 3.

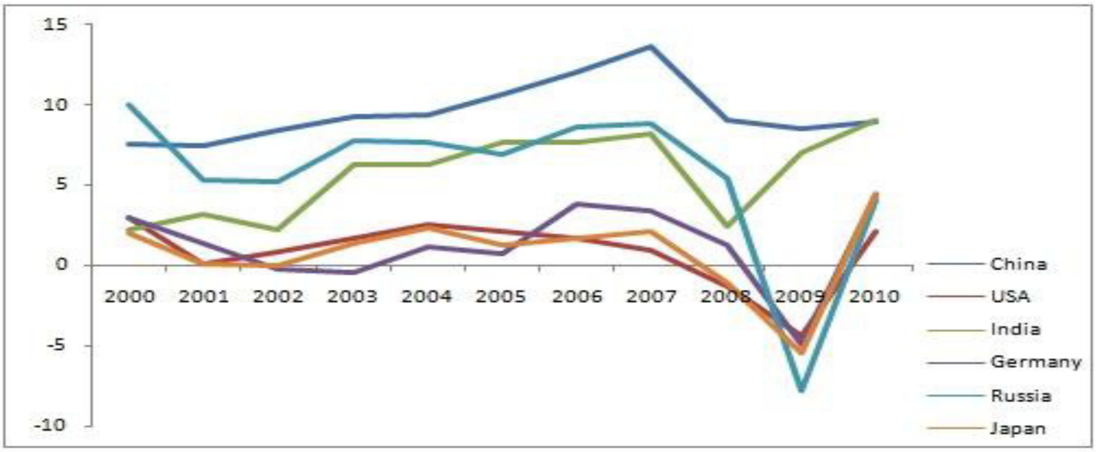

Figure 1 Growth rates of GDP for the six countries (%)

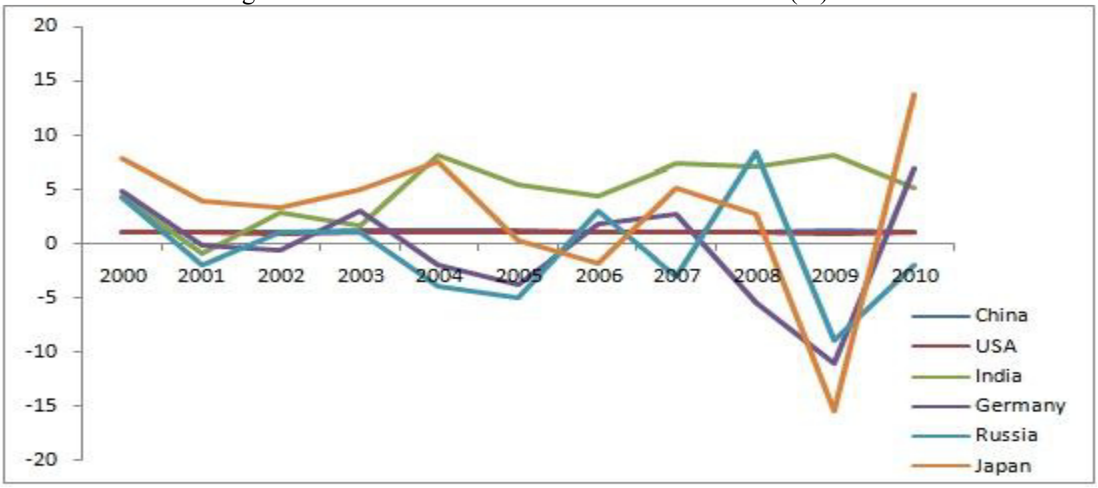

Figure 2 Growth rates of CC for the six countries (%)

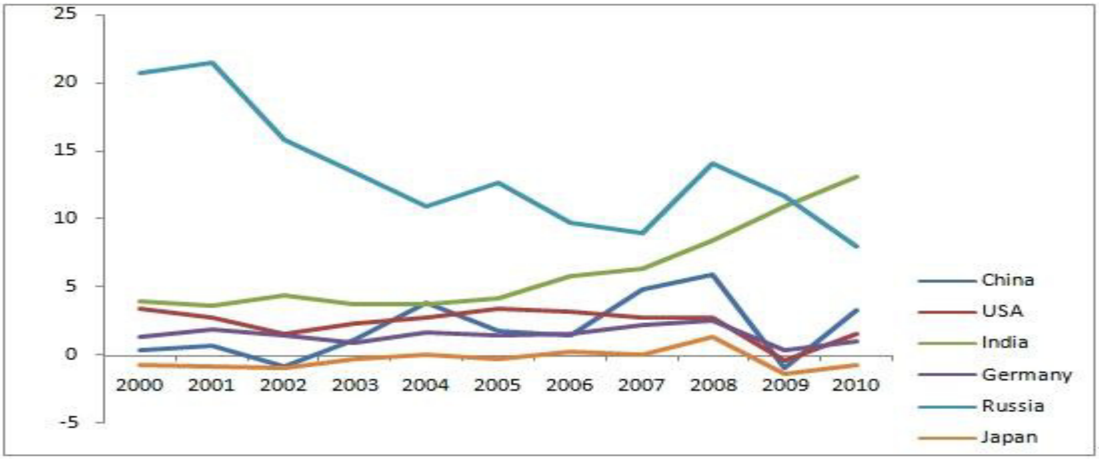

Figure 3 The CPI for the six countries (%)

Table 1 Average annual growth rates during the period 2000-2010 (percent)

Country	CC	CPI	GDP
China	1.09	1.98	9.56
USA	0.98	2.38	0.86
India	4.92	6.22	5.64
Germany	-0.32	1.55	1.23
Russia	-0.65	13.41	5.63
Japan	2.97	-0.31	0.85

Table 1 shows the average annual growth rates of the three data series for the six biggest countries over the period 2000-2010. India's coal consumption increased the most with the percentage of 4.92 followed by Japan, China and USA. Germany and Russia are in minus growth rates in coal consumption. The CPI in Russia is the highest among the six countries followed by India and USA. As for the growth rate of GDP, China is the highest, and India is the second. USA and Japan with little difference, locate at the last.

2.2.Methods

To examine the relationship between CC and GDP for China, VECM is adopted in the study. VECM is vector antoregression modal containing cointegration constraint, often used to build models for non-stationary time series with cointegration relationship. The empirical analysis adopted is separated into three sections, which are unit root tests, cointegration tests and causality analysis.

Panel data model is applied in this study owing to the advantages of the model itself compared with cross section data or time series data models. Panel data model can conduct more comprehensive economic analyses, solve the problem of insufficient samples, allow heterogeneity among different countries and avoid the problems of low degree association with the traditional unit root and cointegration test, containing the information of cross section, time and variables. To examine the relationships in the six countries, the empirical analysis in the paper is separated into three sections in the following, which are panel unit root tests, panel cointegration tests and panel causality analysis.

2.2.1 Panel unit root tests

Sometimes non-stationary time series may show the same tendency in the traditional unit root tests and a higher R square may exist in the regression of the data, which is called spurious regression. To avoid spurious regression and ensure the validity of the results, it is necessary to test the stationary of each panel series.

The advantage of panel data unit root tests is to enhance the test power. The panel unit roots contain the LLC test of Levin, Lin and Chu [34], the IPS test of Im, Pesaran and Shin [35], the Breitung of Breitung [36], the ADF-Fisher and PP-Fisher of Maddala and Wu [37], which are conducted to analyze whether the data are stable.

For the panel data, the following autoregressive (AR) process is considered:

$$y_{it}=\rho_i y_{it-1}+x'_{it}\delta_i+u_{it} \qquad i=1, 2, \ldots, N \qquad t=1, 2, \ldots, T_i \tag{1}$$

Where x_{it} represents exogenous variable including fixed effect and time trend in each section. N represents the number of members of the section. T_i represents the periods of number section i. Parameter ρ_i is the autoregression coefficients. Stochastic error u_{it} is independent and distributes identically. And if $|\rho_i| < 1$, then y_i is a stationary sequence; If $|\rho_i|=1$, then y_i isn't a stationary sequence.

2.2.2 Panel cointegration test

The second part is cointegration test to examine whether the equilibrium relationship exists among the variables in the long-run. Cointegration test contains Pedroni test [38] and Kao test [39], which are both based on Engle and Granger two step methods. This part also contains Johansen panel cointegration test which is based on Johansen test. Johansen test is also called Johansen-Juselius test, which is based on vector autoregression and it is a better method for multivariate cointegration test. Based on the conclusions of the single dependent variable joint test proposed by Fisher, Maddala and Wu [40] put forward Johansen panel cointegration test. If cointegration exists, long-term stable equilibrium relationship should exist among the variables.

Among the three tests above, Johansen test is chosen in this paper for its better multivariate cointegration and its function of determining the number of cointegration relationships among the three variables.

First, the empirical model is established as below and Johansen cointegration test is conducted for the individual section i respectively. Suppose πi is the trace test or the relevant probability of the section i.

$$GDP=\alpha_i + \beta CC_{it} + \gamma CP_{it} + \varepsilon_{it} \quad (2)$$

Second, the statistics of panel cointegration test is established with Fisher's conclusions.

$$Fisher=-2\sum_{i=1}^{n} \ln(\pi i) \quad (3)$$

Maddara and Wu proved the statistics was distributed as chi-square with 2N degrees of freedom gradually [40]. If the null hypothesis is unable to be rejected, it can be indicated there is a corresponding number in the panel data test.

2.2.3 Panel causality analysis

Causality analysis is necessary to be conducted due to the impossibility of cointegration tests in identifying the direction of causality. To obtain the direction of causality, panel VECM (Vector Error Correction Model) proposed by Engle and Granger [41] is used here.

The first step is the long-run model test of the equation (2) to gain the estimated residuals ε_{it}. The second step is to adopt dynamic error correction model to estimate Granger causality. Based on the following regressions, the directions of causality among CC, CP and GDP are examined:

$$\Delta GDP_{it} = \varphi_{1i} + \sum_{p=1}^{m} \varphi_{11ip} \Delta GDP_{it-p} + \sum_{p=1}^{m} \varphi_{12ip} \Delta CC_{it-p} + \sum_{p=1}^{m} \varphi_{13ip} \Delta CP_{it-p} + \theta_{1i}\varepsilon_{it-1} + u_{1it} \quad (4a)$$

$$\Delta CC_{it} = \varphi_{2i} + \sum_{p=1}^{m} \varphi_{21ip} \Delta GDP_{it-p} + \sum_{p=1}^{m} \varphi_{22ip} \Delta CC_{it-p} + \sum_{p=1}^{m} \varphi_{23ip} \Delta CP_{it-p} + \theta_{2i}\varepsilon_{it-1} + u_{2it} \quad (4b)$$

$$\Delta CP_{it} = \varphi_{3i} + \sum_{p=1}^{m} \varphi_{31ip} \Delta GDP_{it-p} + \sum_{p=1}^{m} \varphi_{32ip} \Delta CC_{it-p} + \sum_{p=1}^{m} \varphi_{33ip} \Delta CP_{it-p} + \theta_{3i}\varepsilon_{it-1} + u_{3it} \quad (4c)$$

Where Δ represents the first difference and p is the lag length. The long-run causality will be determined by the equations (4a), (4b) and (4c).

3. Results

3.1 Panel unit roots results and cointegration results

First, descriptive statistics of the sections are shown in table 8. The panel unit root tests of the three variables in levels and in the first difference for six groups are tested in table 9 and table 10. According to table 9, the null hypotheses of the panel unit root can't be rejected in levels for all three variables. Then the panel unit root tests for series in the first difference are tested, the null hypotheses unit root of the three variables are rejected at the significance level of 1%.

Second, Johansen panel cointegration tests examine the long-run equilibrium relationships between the variables. According to table 11, the null hypothesis 'None' indicates there isn't cointegration relationship in the panel and the probability value of the Fisher statistic trace test is 0.0000, thus the null hypothesis is rejected, it can be recognized there is a cointegration relationship at least. The same is the null hypothesis 'At most 1', which indicates there is a cointegration relationship at most and the probability value of the Fisher Statistic trace test is 0.0014, thus the null hypothesis is rejected. It can be deemed there are two cointegration relationships at least. The null hypothesis 'At most 2' implies there are two cointegration relationships in the panel at most and the probability value of the Fisher Statistic trace test is 0.1137, thus the null hypothesis is accepted. It can be judged there are two cointegration relationships at most. So it can be recognized there are two cointegration relationships in the panel.

Similarly, the test results of the Fisher Statistic max-eigen are in line with the test results of the Fisher Statistic trace test, which also show a cointegration relationship in the three variables.

Table 2 Descriptive statistics

	China	USA	India	Germany	Russia	Japan
GDP						
Mean	9.564	0.857	5.637	1.226	5.627	0.850
SD	1.859	2.112	2.620	2.576	4.816	2.534
Skewness	1.022	-1.486	-0.314	-1.067	-2.124	-1.262
Kurtosis	3.117	4.448	1.478	3.942	6.768	4.672
Jarque-Bera	1.921	5.012	1.242	2.496	14.779	4.201
P-value	0.383	0.082	0.537	0.287	0.001	0.122
CC						
Mean	1.085	0.984	4.920	-0.318	-0.655	2.973
SD	0.056	0.056	2.864	5.130	4.852	7.348
Skewness	0.295	-1.034	-0.631	-0.638	0.204	-1.274
Kurtosis	2.312	2.959	2.564	2.888	2.609	4.880
Jarque-Bera	0.377	1.960	0.816	0.752	0.146	4.596
P-value	0.828	0.375	0.665	0.687	0.930	0.100
CPI						
Mean	1.982	2.382	6.224	1.545	13.409	-0.309
SD	2.231	1.111	3.225	0.606	4.438	0.746
Skewness	0.376	-1.498	1.132	-0.050	0.738	0.892
Kurtosis	2.014	4.578	2.893	2.803	2.442	3.664
Jarque-Bera	0.704	5.256	2.354	0.022	1.141	1.661
P-value	0.703	0.072	0.308	0.989	0.565	0.436

(Note: SD, standard deviation)

Table 3 The panel unit root tests for series in levels

Method	Statistic (Prob.**)		
	CC	CPI	GDP
Levin, Lin & Chu t*	-0.26090(0.3971)	-0.87532(0.1907)	-0.72952(0.2328)
ADF-Fisher Chi-square	30.2212(0.0026)***	18.3571 (0.1053)	21.1273(0.0485)**
PP-Fisher Chi-square	45.2100(0.0000)***	29.2802(0.0036)***	33.7721(0.0007)***

Notes:* denotes significance at 10%,** denotes significance at 5%, *** denotes significance at 1%.

Table 4 The panel unit root tests for series in the first difference

Method	Statistic (Prob.**)		
	D(CC)	D(CPI)	D(GDP)
Levin, Lin & Chu t*	-9.68780(0.0000)***	-3.79489(0.0001)***	-6.86072(0.0000)***
ADF-Fisher Chi-square	71.4280(0.0000)***	45.0970(0.0000)***	51.2063(0.0000)***
PP-Fisher Chi-square	91.1879(0.0000)***	79.4081(0.0000)***	67.5836(0.0000)***

Notes: the first difference of unit root tests were with no individual trends or intercepts for each series. * denotes significance at 10%, ** denotes significance at 5%, *** denotes significance at 1%.

Table 5 Johansen panel cointegration tests

Hypothesized	Fisher Stat.* trace test (Prob.)	Fisher Stat.* max-eigen test (Prob.)
None*	120.9(0.0000)***	91.10(0.0000)***
At most 1*	31.87(0.0014)***	26.57(0.0089)***
At most 2	18.07(0.1137)	18.07(0.1137)

Note: * indicates that the null hypothesis is rejected and an alternative hypothesis is accepted.

3.2 Panel causality test results

Based on the tests above, it can be judged there is a long-run cointegration relationship among coal consumption, economic growth and coal price. The directional relationship between coal consumption and economic growth will be helpful in drawing up comprehensive policies. Granger causality test within the panel VECM model is used to detect the causality between the variables.

Table 6 The parameter estimation results of model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
CH (GDP→CC)	8.1643	0.9633	8.4753	0.0000
(CC→GDP)	0.1162	0.1311	0.8868	0.3791
US (GDP→CC))	-2.4716	2.0696	-1.1942	0.2376
(CC→GDP)	-0.1155	0.5102	-0.2264	0.8218
IN (GDP→CC)	0.4051	0.2850	1.4213	0.1610
(CC→GDP)	0.3792	0.3145	1.2059	0.2331
GE (GDP→CC)	0.3922	0.1556	2.5217	0.0147
(CC→GDP)	1.8961	0.3900	4.8620	0.0000
RU (GDP→CC)	0.4173	0.1633	2.5556	0.0134
(CC→GDP)	0.4145	0.1856	2.2335	0.0297
JA (GDP→CC)	0.3044	0.1002	3.0378	0.0037
(CC→GDP)	2.6926	0.3398	7.9230	0.0000

Note: → indicates x does not Granger cause variable y.

From the results shown in table 6, the coefficients of each variable obtained from panel data model are significant. The results indicate that: (1) Bidirectional causal relationships between coal consumption and economic growth exist in Germany, Russia and Japan. (2) Only a unidirectional causality from economic growth to coal consumption exists in China. (3) There are no causal relationships between coal consumption and economic growth in USA and India.

3.3 Discussion

The panel unit root tests for series in levels, in the first difference and Johansen panel cointegration tests are conducted to test the cointegration relationship for the three variables, and the parameter estimation of the model is estimated to judge the direction of causal relationship. The panel unit root tests and Johansen panel cointegration tests prove the data length from 2000 to 2010 is reliable. From the results above, the paper indicates that there is a big difference in causal relationship between coal consumption and economic growth in the six countries.

On the causal relationship from economic growth to coal consumption, the results show there are causal relationships in China, Germany, Russia and Japan. When GDP increases 1% in China, coal consumption will increase by 8.1643%. While GDP increases 1%, coal consumption will increase by 0.3922%, 0.4173% and 0.3044% in Germany, Russia and Japan respectively, which indicates that the same increase in GDP only needs far less consumption of coal in the three countries than in China. It may be the reason that China is still in the developing stage and hasn't advanced technology in coal utilization. These findings coincide with the results in previous research in some way [42].

On the causal relationship from coal consumption to economic growth, the results show when coal consumption increases 1%, economic growth of Japan will rise by 2.6926%, with rise of 1.8961% and 0.4145% in Germany and Russia respectively. It may be assumed that the technology of coal utilization is relatively higher and the idea of energy conservation is deeply cultivated in people' mind since Japan is a country short of energy resource.

The results for USA and India are quite different from those of China, Germany, Russia and Japan. The experimental results show there are no causal relationships among the variables in USA and India since none of the interaction is significant.

4. Conclusions and policy suggestions

The paper tests the causal relationships between coal consumption and economic growth in the six biggest coal consumption countries for the period 2000-2010 using the panel data model, with coal price as a third variable. The empirical findings suggest that bidirectional causal relationships between coal consumption and economic growth exist in Germany, Russia and Japan. Only a unidirectional causality from economic growth to coal consumption exists in China. No causal relationships exist between coal consumption and economic growth in USA and India. From this research, we may conclude as follows.

(1) There is no regular relationship existing between coal consumption and economic growth in the six biggest coal consumption countries.

(2)Each country should follow their own rule when coal consumption and environmental policies are discussed. Nobody of the six countries can achieve success if one country copies the others' policy since the relationship between coal consumption and economic growth is quite different.

(3)As for China, whose efficiency of coal utilization is far behind the other three developed countries, China should invest more in technological innovation and enhance technology improvement in coal utilization, such as clean coal technology, integrated coal gasification and coal liquefaction technology and so on.

Based on the result of low dependence on CC for GDP, Japan may make more use of coal if its energy is in short. For Germany, many coal power projects have been starting since German decided to withdraw from nuclear power. With the increase of thermal power plant and gradually recovering of domestic economy, demand for coal may continue to increase in the future for Germany. So Germany should establish clean and reasonable coal utilization policies to increase coal consumption.

For Russia, due to its bountiful reserves of coal resource, Russia can further expand the domestic consumption market, accelerate the construction of coal powered plant and the railway, port and other transportation facilities in the future so as to reduce the demand for the expensive natural gas.

For USA and India, coal may be an important supplement of energy supply when it is needed.

(4)Similar researches should be expected both in more countries and with more reliable methods.

As the relationship between coal consumption and economic growth is probably quite different in different countries, it is necessary to do individual researches for different countries to provide more reliable bases for their policy and decision-making of coal consumption and economic growth in each country

This study only does a comparative analysis of eleven years in the biggest coal consumption countries due to the unavailability of data. The study can be extended both in time length and methods when conditions permit in the future. Individual studies can also be conducted with available data of each country separately. Or we may try to employ other methods to do relevant study, like vector autoregression model, vector error correction model, autoregression distributed lag and so on.

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