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Analyzing the Long-Term Linkage between Industrial Energy Consumption and Economic Growth in Beijing-Tianjin-Hebei Delta: Based on Cobb-Douglas Production Function

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Abstract

Based on Cobb-Douglas production function, this paper firstly uses the unit root test and cointegration test to study cointegration relationship between labor input, capital stock, coal consumption, natural gas consumption and industrial economic growth in Beijing-Tianjin-Hebei region from 1995 to 2014. Secondly, the Granger causality test is used to explore the causal linkage between coal consumption, natural gas consumption and industrial economic growth in Beijing-Tianjin-Hebei delta. An OLS method is used for regression. The empirical results show that there is a long-run cointegration relationship between the above five variables in Beijing-Tianjin-Hebei Delta; Beijing's industrial economic growth Granger causes coal and natural gas consumption. On the contrary, the coal and natural gas consumption in Tianjin and Hebei Granger cause industrial economic growth; The output elasticity of coal consumption are 0.6264%, 0.9608% and 0,8272%, and the output elasticity of natural gas consumption are 0.1902%, 0.2442% and 0.0870% in Beijing, Tianjin, and Hebei respectively. Finally, from the perspective of sustainable economic development, this paper puts forward some suggestions on the structure and mode of energy consumption in Beijing-Tianjin-Hebei Delta.

Keywords

Industrial Energy consumption; Economic growth; Beijing-Tianjin-Hebei Delta; Cobb-Douglas production function.

1. INTRODUCTION

Energy is an indispensable material basis for human survival and social development (Ma et al., 2012). With the development of industrial economic growth, China's energy consumption continues to increase, resulting in serious air pollution, especially in the Beijing-Tianjin-Hebei delta. As one of the three poles of China's economy, Beijing-Tianjin-Hebei delta accounted for 9.87% of the total economic growth in 2013 (China's Statistical Yearbook, 2014). To support the rapid economic development, the proportion of its energy consumption in the total energy consumption highly reached 10.36% (China's Energy Statistical Yearbook, 2014). In addition, the Beijing-Tianjin-Hebei delta is densely populated with high energy-consuming and high-emission enterprises. Huge consumption of fossil fuel in Beijing-Tianjin-Hebei delta leads to its air pollutant emission level about four times of the national average (http://env.people.com.cn/n1/2017/0107/c1010-29005852.html). Beijing-Tianjin-Hebei delta has become one of the most severely polluted area in China. Nowadays, the Beijing-Tianjin-Hebei delta is facing the major task of adjusting the energy consumption structure to improve the environment and promote the high-quality economic development. Therefore, effectively

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studying the relationship between energy consumption and industrial economic growth in Beijing-Tianjin-Hebei delta is one of the issue that needed to be solve.

The linkage between energy and economy has been a hot topic for a long time in the research area (Troster et al., 2018). Since the American researcher Granger (1969) first proposed the Granger causality test in 1969, the research field of causality test has been greatly developed. Subsequently, the research on the relationship between energy consumption and economic growth using Granger causality test was quickly applied to American, Ghana, South Africa, Bangladesh, and other countries (Kraft and Kraft, 1978; Appiah, 2018; Menyah and Wolde-Rufael, 2010; Naser, 2015; Rahman & Kashem, 2017). With the deepening of research on causality test, a large number of new theories have begun to be used in causality test, such as panel cointegration theory, autoregressive model. Considering the heterogeneity of energy, Liang et al. (2013) studied the relationship between China's total energy consumption, coal consumption, oil consumption, electricity consumption, and economic growth using the linear Toda-Yamamoto and the non-linear Diks-Panchenko Granger causality test. They found that reducing energy consumption will have a certain impact on China's economic growth. Riti et al. (2017) used the panel cointegration theory to test the relationship between China's non-renewable energy, renewable energy, and GDP from 1971 to 2013. Their results showed that there was a bidirectional causality between renewable energy, non-renewable energy, and economic growth in the long-run. Ummalla and Samal (2018) used the Auto Regressive Distributed Lag (ARDL) model to study the relationship between China's hydropower energy consumption and the economy. They found that hydropower energy consumption has a positive impact on promoting China's economic growth.

As Rasche and Tatom (1977) first added energy consumption into the Cobb-Douglas (C-D) production function to explore the relationship between it and economic growth, which provides another new basic research framework for other scholars who study the relationship between the two. Subsequently, Zhao and Wei (1998) first added energy variables into the C-D production function in the research process of China's economic growth. They found that the expanded form of the C-D production function is more in line with China's actual economic development process. Considering the impact of energy consumption on environment, Wang et al. (2016) quantitatively analyzed the transmission relationship between energy, economy and carbon emission in China from 1990 to 2011 with energy as the intermediate variable. The research showed that 1% increase in economic growth, energy consumption and carbon emission increased by 1.5177% and 1.5722% respectively. Since energy types contribute differently to the economic growth, Le and Sarkodie (2020) studied the nexus between the utilization of renewable energy, conventional energy, and economic growth in 45 Emerging Market and Developing Economies based on C-D production function. They found that both renewable energy consumption and conventional energy consumption play an important role in promoting economic growth for the research objects.

The research of the above scholars has certain research significance, but most of them focus on a single country or a single region, and has not studied the key polluted areas in a single country. Therefore, this paper focuses on analyzing the long-run relationship between industrial energy consumption and economic growth in Beijing-Tianjin-Hebei delta, which is one of the most polluted area in China. The paper is organized as follow: Section 2 describes the model and data source; Section 3 provides the results of unit root test, cointegration test, Granger causality test, and regression; Finally, in Section 4, we summarize the paper and give some policy recommendations.

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2. THE MODEL AND DATA SOURCES

2.1. The Model

Based on the research methods of other scholars (Apergis& Payne, 2012; Lee & Chang, 2008; Sari and Soytas, 2007), this paper employs a Cobb-Douglas production model that integrates the five variables: industrial coal consumption, natural gas consumption, labor input, capital stock, and economic growth. The industrial economic growth brought by coal and natural gas consumption meets the following mathematical forms:

$$Y_i = A_i L_i^{\alpha_i} K_i^{\beta_i} d_{i1}^{\tau_i} d_{i2}^{\omega_i}.$$

Where: Y_i is the industrial economic growth of administrative region i , A_i is the total factor productivity of administrative region i, L_i is the industrial labor input of administrative region i, K_i is the capital stock of administrative region i, di1 is the coal consumption of administrative region i, d_{i2} is the natural gas consumption of administrative region i. α_i, β_i, τ_i, ω_i are the elasticity coefficient of labor input, capital stock, coal consumption and natural gas consumption of administrative region i respectively.

2.2. Data Sources

The empirical study was based on the annual data collected from 1995 to 2014 from major statistical yearbooks: the Beijing Statistical Yearbook, Tianjin Statistical Yearbook, Hebei Statistical Yearbook, China's Energy Statistical Yearbook. This paper collects the industrial economic growth, industrial labor input, and industrial capital stock in the Statistical Yearbook of Beijing, Tianjin, and Hebei. In some regions, the industrial economic growth is not directly given in the statistical yearbook of some years. According to China's definition of industry, this paper holds that industrial GDP is equal to the sum of the total economic growth of three industries: extractive industry, manufacturing, and the production and supply of electricity, water, and gas. Industrial coal consumption and natural gas consumption are obtained by adding up the terminal energy consumption, processing conversion, and energy loss in the energy balance table of Beijing, Tianjin, and Hebei in the China's energy statistical yearbook.

3. EMPIRICAL STUDY

3.1. Unit Root Test

Before conducting the cointegration test, stationary tests must be advanced to avoid the false regression. This paper adopts the Augmented Dickey and Fuller (ADF) method to test the stationarity of the second-order differences of LnK_i, LnL_i, Lnd_{i1}, Lnd_{i2}, LnY_i. The test results are shown in the Table 1.

Table 1. The results of unit root test

Region	Beijing	Tianjin	Hebei
$\Delta^2 LnL_i$	-6.4002 (-1.9710)	-4.2338 (-1.9710)	-5.2628 (-1.9710)
$\Delta^2 LnK_i$	-4.7743 (-1.9740)	-2.9947 (-1.9710)	-3.4834 (-1.9710)
$\Delta^2 Lnd_{i1}$	-4.8525 (-1.9777)	-5.2066 (-3.8290)	-8.4599 (-3.8290)
$\Delta^2 Lnd_{i2}$	-2.9874 (-1.9823)	-5.8038 (-3.8753)	-4.0950 (-1.9823)
$\Delta^2 LnY_i$	-5.1022 (-3.8753)	-5.2615 (-3.8289)	-4.1718 (-3.8290)

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Notes: The number in the first row of the table is the ADF value of the each variable, and the critical value under 5% significance level is in parentheses.

Table 1 shows that the absolute value of the ADF of labor input, capital stock, coal consumption, natural gas consumption and industrial economic growth in Beijing, Tianjin and Hebei are greater than the critical value under the 5% significance level. Therefore, this paper assumes that the above variables satisfy the premise of the cointegration test.

3.2. Cointegration Test

Since labor input, capital stock, coal consumption, natural gas consumption and industrial economic growth are all second-order single integration, this paper uses the Engle-Granger two-step method to test the cointegration relationship of the above five variables to further eliminate the spurious regression. The test results of the residual sequence are shown in the Table 2.

Table 2. The results of cointegration test

Region	(c,t,k)	ADF value	Critical value		
			1%	5%	10%
Beijin	(0,0,3)	-2.1758	-2.7283	-1.9663*	-1.6050*
Tianjin	(0,0,3)	-4.7384	-2.7406*	-1.9684*	-1.6044*
Hebei	(0,0,3)	-5.8240	-2.7283*	-1.9663*	-1.6050*

Notes: c, t and k respectively represent intercept term, trend term and lag order; * means stable under this significance level.

From Table 2, we can obtain that the residual series of Beijing, Tianjin and Hebei are all stable under 5% and 10% confidence levels, which shows that there is a long-term stable equilibrium relationship among the labor input, capital stock, coal consumption, natural gas consumption and industrial economic growth.

3.3. Granger Causality Test

Table 3. The results of Granger causality test

Region		P value	Lags	10%
Beijing	Y_1 is not the Granger cause of d_{11}	0.0012	3	Reject
	d_{11} is not the Granger cause of Y_1	0.7184		Accept
	Y_1 is not the Granger cause of d_{12}	0.0155		Reject
	d_{12} is not the Granger cause of Y_1	0.3992		Accept
Tianjin	Y_2 is not the Granger cause of d_{21}	0.8385	3	Accept
	d_{21} is not the Granger cause of Y_2	0.0413		Reject
	Y_2 is not the Granger cause of d_{22}	0.9533		Accept
	d_{22} is not the Granger cause of Y_2	0.0978		Reject
Hebei	Y_3 is not the Granger cause of d_{31}	0.3966	3	Accept
	d_{31} is not the Granger cause of Y_3	0.0909		Reject
	Y_3 is not the Granger cause of d_{32}	0.1882		Accept
	d_{32} is not the Granger cause of Y_3	0.0661		Reject

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From the cointegration test, we obtain that there is a long-run stable equilibrium relationship among the above five variables. In order to explore the relationship between different energy types and industrial economic growth in the equilibrium relationship, Granger causality should be tested furtherly. The test results are shown in the Table 3.

As shown in the Table 3, Beijing's industrial economic growth is the Granger cause of coal consumption and natural gas consumption, conversely is not. However, in Tianjin and Hebei, the coal consumption and natural gas consumption are the Granger cause of industrial economic growth respectively.

The reason for the above results are: for Beijing, the promulgation of atmospheric laws and regulations has caused a large number of coal-fired plants to close or relocate, which resulting in the decreasing in coal consumption. Beijing's industrial development is now increasingly focused on energy conservation, environmental protection, and technological innovation. The main limiting factor for the development of Beijing's industrial economy has gradually turned into technological innovation. However, for Tianjin and Hebei, their industrial development and innovation technology are relatively backward. In addition, the state has been emphasizing "to relieve Beijing of functions non-essential to its role as China's capital", which has resulted in the relocation of a large number of factories from Beijing to Tianjin and Hebei and has increased the consumption of coal and natural gas in Tianjin and Hebei.

3.4. Regression Results

The regression results for Cobb-Douglas production function of Beijing, Tianjin, and Hebei are shown in Table 4 using the OLS (ordinary least squares) method.

Table 4. The result of regression

Region	Cobb-Douglas production function	R^2
Beijing	$Y_1 = 0.4948L_1^{-0.0747}K_1^{0.5590}d_{11}^{0.6264}d_{12}^{0.1902}$	0.9513
Tianjin	$Y_2 = 0.02042L_2^{0.2714}K_2^{0.2731}d_{21}^{0.9608}d_{22}^{0.2442}$	0.9899
Hebei	$Y_3 = 130.3381L_2^{0.2714}K_2^{0.2731}d_{21}^{0.9608}d_{22}^{0.2442}$	0.9906

The above results show that 1% increase in coal consumption, the industrial economic growth of Beijing, Tianjin, and Hebei will increase by 0.6264%, 0.9608%, and 0.8272% respectively, 1% increase in natural gas, the industrial economic growth of Beijing, Tianjin, and Hebei will increase by 0.1902%, 0.2442%, and 0.0870% respectively. The industrial coal consumption in Tianjin and Hebei has a stronger impact on the industrial economic growth than Beijing, whereas the natural gas consumption in Tianjin has a stronger impact on industrial economic growth than Beijing and Hebei.

4. CONCLUSION AND SUGGESTION

This paper has examined the empirical cointegration, long-run and causal relationships among industrial coal consumption, natural gas consumption, and economic growth in case of the Beijing-Tianjin-Hebei delta over the period of 1995-2014. The results show that there is a long-run relationship between industrial energy consumption and economic growth in the Beijing-Tianjin-Hebei delta. Beijing's industrial economic growth Granger causes coal and natural gas consumption. On the contrary, the coal and natural gas consumption in Tianjin and Hebei Granger cause industrial economic growth. Based on the above results, this paper puts forward the following suggestions to facilitate the sustainable development of the Beijing-Tianjin-Hebei delta. First, each administrative region in the Beijing-Tianjin-Hebei delta should adjust the energy structure and promote the infrastructure of renewable energy to furtherly

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increase the proportion of renewable energy in the total energy consumption. Second, increase investment in clean coal technology. The high consumption of coal leads to high emission of industrial waste gas, and then leads to serious air pollution. Therefore, each administrative region should develop coal exhaust treatment technology vigorously. Third, Carry out overall planning of regional coal resources. Due to the geographical proximity of Beijing, Tianjin and Hebei, the energy planning of each administrative region can be jointly studied to achieve the purpose of reducing coal consumption and saving resources furtherly.

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