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Relationship between Energy Consumption and Economic Growth: Empirical Study Based on Data on Hebei Province from 1980 to 2008

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Abstract

This paper uses the methods of co-integration analysis and Granger Causality test, analyses the relationship between energy consumption and economic growth of Hebei Province from 1980 to 2008. The empirical results show that there is a stable causal relation between TEC and GDP in the long run. Hebei's economic growth contributes to energy consumption growth. To change economic development mode and save energy，reduction of pollutant emission will not only impact the economic growth，but also achieve energy-saving，emission reduction and sustainable development.

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Keywords:energy consumption;economic growth; cointegration analysis;Granger Causality test introduction

1. Introduction

Today，the issues of energy and environment are concerned all over the world，and becoming more and more important in our social and economic development. With the rapid economic growth and development，the contradiction between economic growth and energy consumption is increasingly prominent. Relating to energy consumption and economic growth，domestic and international scholars have done a lot of research to discuss that has economic growth resulted in energy consumption or has the energy consumption promoted economic growth or they are.

Hebei locates in north china，and is an important province in energy production and consumption. At present the relevant research between economic growth and energy consumption in Hebei province is very limited. Therefore, this study is to analyse the relationship between GDP and the total energy consumed in Hebei province by the methods of co-integration analysis and Granger Causality test according to the data from 1980 to 2008 ,total 29 sets of annual data.

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2. The status of energy development and economic growth in Hebei province

2.1. The analysis of energy consumption and economic growth trends

Coal、oil、gas and electricity are the main energy consumed in Hebei province. Coal shares the largest proportion，accounting 92.35% in 2008. From 1980 to 2008, energy consumption of Hebei has increased from 312.05 to 24225.68 ten thousand tons of coal equivalent (Fig 1), increasing 7.76 times, and the average annual growth rate reaches 7.71%. The energy consumption of first industry is 612.36 ten thousand tons of coal equivalent in 2008, occupying 2.5% of the total energy consumption ;the second industry is 18487.76 ten thousand tons of coal equivalent，occupying 82.1%; the third industry is 1781.44 ten thousand tons of coal equivalent Occupying 7.4%;and the residents living consumption is 1946.36 ten thousand tons of coal equivalent ，Occupying 8%. The industry still shares the largest proportion in energy consumption. In the meantime, the GDP of Hebei has increased from 219.24 billion yuan to 16188.61 billion yuan, the average annual growth rate is 10.7%. The energy consumption and GDP of Hebei shows a steady rising trend , and we can preliminarily assess that there exists some kind of relationship between the energy consumption and economic growth.

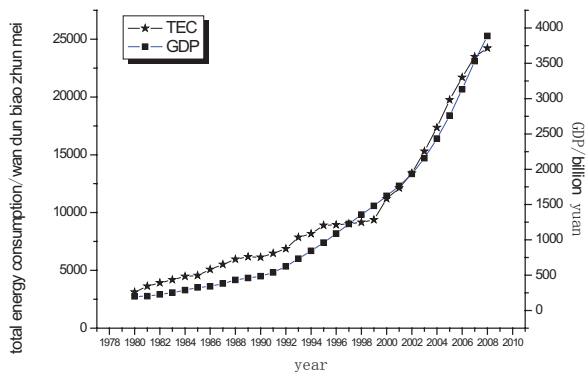

Figure 1 The trend of total energy consumption and GDP (at the constant prices of 1978)in Hebei from 1980 to 2008

2.2. Elasticity coefficient of energy consumption

The elasticity coefficient of energy consumption is a indicator which is to reflect the proportion of energy consumption growth rate and national economic growth rate.

Elasticity coefficient of energy consumption = Average growth rate of energy consumption / Average annual growth rate of the GDP

In figure 2 the curves show that the trend of energy consumption elasticity coefficient in Hebei is similar to the nation and highly fluctuates without obviously regularity. From 1982 to 2008 the average annual elasticity coefficient of energy consumption is 0.70, higher than 0.65 of the nation. Since 2000,the elasticity coefficient of energy consumption is greater than 1 (except 0.94 in 2001). It shows that the economy development of Hebei has entered a new rapid growth stage, due to the characteristics of industrial structure, rapid economic growth results from the rapid growth of high-energy industries like steel, cement and so on.

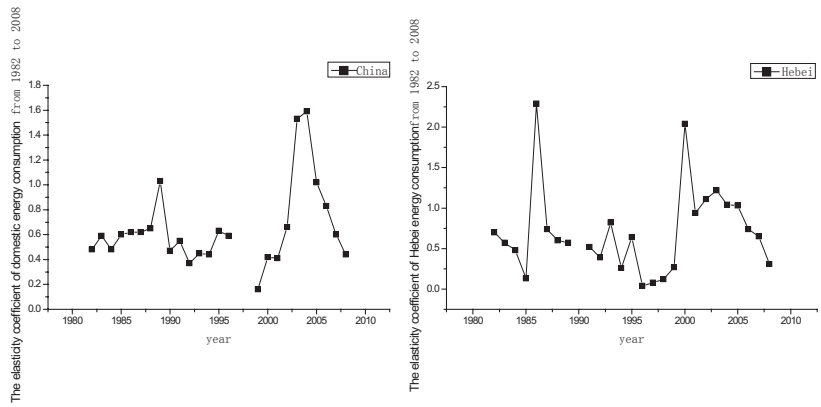

Figure 2: Fluctuations of energy consumption elasticity coefficient between China and Hebei Province from 1982 to 2008

2.3. Intensity of energy consumption

Energy consumption intensity indicates the amount of energy used by unit of GDP, calculated as:
Energy consumption intensity = Total Energy Consumption/ ten thousand yuan GDP(at the constant prices of 1978), its unit commonly is tons of coal equivalent(TCE) / ten thousand yuan.

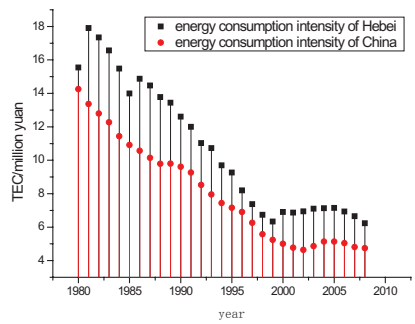

Figure 3 intensity change of energy consumption between China and Hebei Province from 1980 to 2008

In figure 3 the curves show that the energy consumption intensity in Hebei has been declining from1980 to 2008, falling from 15.55 TCE / ten thousand yuan to 6.23 TCE / ten thousand yuan, and is consistent with the national energy consumption intensity. It states that the efficiency of energy utilization is gradually improving and the energy-saving effect is obvious in Hebei, owing to the technology innovation and adjustment of industrial structure. But compared with the national energy consumption intensity, Hebei's energy consumption intensity is far higher than the nation. So there is still a large space for Hebei in energy- saving and emission reduction in the future.

3. Empirical analysis of energy consumption and economic growth

3.1. The selection of variables and data

Raw data comes from the 《Hebei economic yearbook》 [8]and 《 China statistical yearbook》 [9]. Data interval is

from 1980 to 2008. The total energy consumption (TEC) is a physical indicator, its unit is ten thousand tons of coal equivalent(TCE). The GDP is based on the constant prices of 1978. In order to eliminate the fluctuation among data, the data of GDP and energy consumption will be taken logarithmic and recorded as LGDP and LTEC.

3.2. Sequence stationary test

This paper adopts unit root ADF test methods, and the ADF test is executed through the following three model :

$$\text{Model: } \Delta y_t = \delta y_{t-1} + \sum_{j=1}^{p} \lambda_j \Delta y_{t-j} + u_t$$

$$\text{Mode2: } \Delta y_t = \mu + \delta y_{t-1} + \sum_{j=1}^{p} \lambda_j \Delta y_{t-j} + u_t \tag{3.1}$$

$$\text{Mode3: } \Delta y_t = \mu + \beta t + \delta y_{t-1} + \sum_{j=1}^{p} \lambda_j \Delta y_{t-j} + u_t$$

P usually adopts Akaike information criterion (AIC) or Schwartz criteria to determine.
The inspection is to test the null hypothesis(H_0: $\delta = 0$)through the ADF critical value table after having estimated the proper forms of these three models. As long as the test result of any model could despise the null hypothesis ($t_\delta \prec \tau$), it is considered that time series is smooth. When all of three test results could not reject the null hypothesis ($t_\delta \succ \tau$),it is considered that time series is not smooth.

Using the econometric software Eviews5.0, we completed the stationary test of LGDP and LTEC sequences of Hebei province, the results are shown in table 1.

Table 1 The unit root test of energy consumption LTEC and LGDP

Variables	Model	ADF	Critical value			Stability results
			α=1 %	α=5 %	α=10 %	
LTEC	1	2.229394	-2.656915	-1.954414	-1.609329	non-stationary
	2	0.607825	-3.711457	-2.981038	-2.629906	non-stationary
	3	-2.05856	-4.356068	-3.595026	-3.233456	non-stationary
ΔLTEC	1	-1.14283	-2.66072	-1.95502	-1.60907	non-stationary
	2	-2.69964	-3.72407	-2.986225	-2.632604	α=10 % stationary
	3	-2.81223	-4.374307	-3.603202	-3.238054	non-stationary
LGDP	1	2.882229	-2.656915	-1.954414	-1.609329	non-stationary
	2	0.374057	-3.711457	-2.981038	-2.629906	non-stationary
	3	-2.53697	-4.356068	-3.595026	-3.233456	non-stationary
ΔLGDP	1	-0.32875	-2.66072	-1.95502	-1.60907	non-stationary
	2	-2.96093	-3.72407	-2.986225	-2.632604	α=10 % stationary
	3	-2.85149	-4.374307	-3.603202	-3.238054	non-stationary

According to table 1, LTEC and LGDP sequences are not stable in the significant level of $\alpha = 1\%$, $\alpha = 5\%$, $\alpha = 10\%$. With ΔLTEC and ΔLGDP in the significant level of $\alpha = 10\%$, ADF value is less than critical value in model (2), and $\alpha = 10\%$‖LTEC1I（1），LGDP1I(1)‖, so the two sequences could further execute co-integration test.

3.3. The co-integration analysis of energy consumption and economic growth

Co-integration test (Engle-Granger of two variables) is proposed by Engel and Granger in 1987, also known as EG test or augmented Engel and Granger method (AGE)[11]. The step is as follow. If the variables are smooth, the entire test process may stop, because you can deal them with standard regression technique. If the variables are non-stationary, it should be done to find out the ARIMA of two variables, and then separately handle them. If the

ARIMA of two variables are different, the two variables aren't be co-integration. If they are same, it is necessary to enter the next step of inspection procedure.

1.The first step is to estimate the long-term equilibrium equation (called co-integration regression) through the method of OLS if the ARIMA of variable y_t and variable x_t are same , it's

$$\hat{y}_t = \hat{b}_0 + \hat{b}_1 x_t \tag{3.2}$$

and save the residual $e_t = y_t - \hat{y}_t$, as the estimate value of balanced error u_τ .

2. The second step is to inspect the stationary of residual item e_t . If e_t is stationary, then y_t and x_t are co-integrated, there is a long-term equilibrium relationship between y_t and x_t ; Otherwise instead.

According to table 1 ,LGDP and LTEC are first order stationary, and should execute co-integration two-step inspection.

The first step is to get the long-term equilibrium equations of LGDP and LTEC by using method of least squares:

$$\mathrm{LTEC}_t = 4.860439 + 0.619558\,\mathrm{LGDP}_t \tag{3.3}$$

$$\text{t=(35.18431)} \quad \text{(30.43969)}$$

$$R^2 = 0.971685\text{, DW=0.287728，F=926.5745}$$

The second step is to test the residual sequences with unit root test methods. The ADF value of model(1) that does not include intercept item and tendency item is -2.168843, and the critical values are -2.656915, -1.954414, -1.609329 based on $\alpha = 1\%$、$\alpha = 5\%$、$\alpha = 10\%$. The test result shows that the residual of model (2.4) is stationary in the level of $\alpha = 5\%$, and the LTEC and LGDP is (1, 1) order co-integration, there is a long-term equilibrium relationship between them.

Judging from the t value and regression results, R^2、F、t are all through the significant test. But DW value slants small, the residual sequence has a first and second auto-correlation. In order to eliminate the influence, the general differential method and Eviews5.0 are used to get a new model, and the balanced equations for LTEC and LGDP are:

$$\mathrm{LTEC}_t = 4.528764 + 0.665076\mathrm{LGDP}_t \tag{3.4}$$

$$\text{t=（7.489824）　（8.139116）}$$

$$R^2 = 0.993832\text{, DW=2.109999，F=1235.320}$$

$$\text{AR(1)= 1.141396 AR（2）=-0.284710}$$

$$\text{t=（6.735097）　（-1.615738）}$$

Based on the equilibrium equation(2.5), the value of ADF(-2.619548) is less than the critical test value of -1.955020($\alpha = 5\%$), thus the residual sequence is stationary and eliminates auto-correlation influence.

Analysis result shows that both the total energy consumption and GDP exist co-integration relationship in Hebei province from 1980 to 2008. According to the co-integration regression equation executed by general differential, the energy consumption and economic growth in Hebei province exist positive correlation, TEC will increase ten thousand coal equivalent, while GDP has increased additional 0.665076 billion yuan.

3.4. Granger causality test

Co-integration test shows that whether there has a long-term equilibrium relationship among variables , but further inspection will be required about whether there exists the causal relationship . For Granger causality test, there is a assumption that every predicted information of variable y and variable x are all contained in time series. The following return is required to estimate by inspection:

$$y_t = \sum_{i=1}^{q} \alpha_i x_{t-i} + \sum_{j=1}^{q} \beta_j y_{t-j} + u_{1t} \tag{3.5}$$

$$x_t = \sum_{i-1}^{s} \lambda_i x_{t-i} + \sum_{i-1}^{s} \delta_j y_{t-j} + u_{2t} \tag{3.6}$$

Here, it is assumed that u_{1t} and u_{2t} are not related.

To(3.5), it's zero hypothesis;
To(3.6), it's zero hypothesis.

If the F value which is calculated under the selected α exceeds the F_a value, then zero hypothesis is refused , and the lagged x belongs to this return, it declares that x is the reason of y. Similarly, in order to check whether y is the reason of x, the variable x and variable y could be interchangeable [12].

Table 2 Granger causality test between TEC and GDP

Test	Lags	Observation	F value	P value
TEC does not Granger Cause GDP	2	27	2.72096	0.08792
GDP does not Granger Cause TEC			2.02760	0.15553
TEC does not Granger Cause GDP	3	26	0.73535	0.54379
GDP does not Granger Cause TEC			3.86153	0.02592
TEC does not Granger Cause GDP	4	25	0.38685	0.81490
GDP does not Granger Cause TEC			3.02824	0.04895

According to table 2, "GDP is not the Granger reason of TEC" is refused under $\alpha = 5\%$, so GDP is the reason of TEC; and "TEC is not the Granger reason of GDP" is not refused , then TEC is not the reason of GDP. Causality test shows that there exists one-way causality of economic growth to the consumption of energy in Hebei province from 1980 to 2008. It also accords with the economic theory that GDP and energy prices are the main factors that will affect the energy consumption.

4. Conclusions and Suggestions

The energy consumption and economic growth in Hebei province is raising steadily from 1980 to 2008, the volatility of energy consumption elasticity coefficient is great without obvious variation tendency, and the energy consumption growth is very unstable. Energy consumption strength is declining year by year, but still above the national level. Co-integration analysis shows that there exists co-integration relationship between energy consumption and GDP in Hebei province. In the long-term, GDP has increased additional 0.665076 billion yuan, TEC will increase ten thousand tons coal equivalent. The relationship between energy consumption and GDP growth in Hebei is one-way causality, so economic growth is the Granger causes of energy consumption, but the reverse causality is not established.

Research results show that the economic growth is the main influence factor of energy consumption in Hebei province, the transformation of economic development mode not only won't affect economic growth of Hebei province, but also helps to reduce energy consumption, implement the policy of energy saving and emission reduction.

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