ISSN: 2692-7608 DOI: 10.6981/FEM.202108_2(8).0023

Study on the Relationship between Chinese Energy Consumption and Economic Growth

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Abstract

The problem of climate change caused by excessive energy consumption has attracted worldwide attention to economic development patterns. Based on China's GDP, fossil energy and other energy consumption data from 1998 to 2018, this paper studies the relationship between China's economic growth and energy consumption by establishing an econometric model. The results of the co-integration equation show that there is a stable long-term equilibrium relationship between the consumption of oil, natural gas and other energy resources and economic growth, and that natural gas consumption has a significant impact on China's economic growth. Every 1% increase in GDP will lead to 9.0436% increase in natural gas consumption. Granger causality test shows that economic growth is the cause of energy consumption growth, but the increase of energy consumption is not the cause of economic growth. The error correction model shows that in the short term energy consumption is adjusting to the long-term equilibrium very quickly. Finally, based on the empirical results, some countermeasures and Suggestions are put forward to maintain China's economic development and reduce its dependence on fossil energy.

Keywords

Energy Consumption; Energy Structure; Co-integration Test; ADF Test; Granger Causality Test.

1. Introduction

There is a very close and important relationship between energy and economic growth. Energy has become an important material guarantee for the stable development of a country's economy and provides the necessary impetus for economic growth. The demand for and dependence of economic growth on energy will also increase. Economic growth has improved energy efficiency and optimized the energy consumption structure. In addition, environmental problems caused by energy consumption have become an obstacle to economic growth. With the impact of economic growth and the oil crisis, governments of all countries have formulated energy strategies, which makes the relationship between energy consumption and economic growth a hot issue in economics. Therefore, in-depth study of the relationship between energy consumption and economic growth is of great significance for supporting the sustainable development of China's economy and society and solving the traditional fossil energy crisis.

The relationship between energy consumption and economic growth is a hot issue in the field of economics. Scholars at home and abroad have conducted a lot of theoretical discussion and empirical research on the relationship between the two. When studying the relationship between energy input factors and economic growth, foreign scholars divide it into two research directions: exogenous technological progress and endogenous technological progress. The first is the study of exogenous technological progress; the second is the realization of sustainable economic growth through endogenous technological progress. The representative studies are as follows: Kraft et al. [1] used a bivariate causality test method to study both energy consumption and economic growth. Yu et al. [2] used quarterly data from the United States and

ISSN: 2692-7608 DOI: 10.6981/FEM.202108_2(8).0023

adopted the E-G two-step method to carry out causality test and found that there was no long-term cointegration equilibrium relationship between the two. In the long run, there was no causal relationship between the two in any direction; Stern [3] used vector autoregressive model and concluded that there was no Granger causality between total energy consumption and GDP. Lee [4] constructed a three-variable model, using heterogeneous panel cointegration and causality testing methods, and showed that there is a one-way causal relationship from energy consumption to economic growth in 18 developing countries.

The research on energy consumption and economic growth by domestic scholars started relatively late. Wang et al. [5] used the measurement method to conclude that different policies must be formulated in different parts of China to reduce carbon dioxide emissions. Qi et al. [6] used regression analysis to derive energy consumption intensity, studied the influencing factors of the difference between China and eight developed countries, and explored the mechanism of energy consumption intensity changing with per capita GDP. Zeng et al. [7] pointed out the inherent proportional relationship between the two, and measured the increase in GDP brought about by the increase in energy consumption, to evaluate and found the changing trend of energy efficiency.

In summary, foreign scholars have studied the relationship between energy consumption and economic growth relatively early, but they mostly conduct macro-level research. However, domestic scholars started relatively late in research in this area, and generally conducted empirical research by using my country's data. There is still no unified framework and a solid and reliable theoretical basis.

2. Research methods and data sources

2.1. Research method

In order to verify the correlation between energy consumption and economic growth variables, an appropriate regression equation is usually established based on the existing sample data. The premise of regression analysis is that all time series must be stationary, otherwise "false regression" phenomenon will appear. Therefore, in this paper, the stationarity test (unit root test) is first carried out for each time series before testing whether there is a long-term co-integration relationship between variables. There are many methods of unit root test. Commonly used methods include DF test, ADF test and PP test. In this paper, ADF test method is used to test the unit root of the sequence. The cointegration test between variables can be performed if the time series passes the stationarity test and is the same order single sequence. Engle-Granger two-step method and Johansen maximum likelihood method are the most commonly used methods to test and estimate the co-integration relationship. The former is suitable for the cointegration test between two variables, while the latter is suitable for the cointegration test between multiple variables. The purpose of this paper is to study the relationship between various energy consumption and economic growth, so E-G two-step method is chosen to conduct co-integration test. The co-integration relationship is the long-term equilibrium relationship between variables. If two variables have a co-integration relationship, the short-term non-equilibrium relationship between them can always be expressed by an error correction model. Finally, the Granger causality test between variables will be performed at different lag orders.

2.2. Variables and data sources

For the sake of the availability of data and the need of research, there are mainly four indicators selected in this paper, namely coal consumption (CC), oil consumption (PC), natural gas consumption (NC) and primary electricity and other energy consumption (OC). The data in this article are derived from China Statistical Yearbook, taking the annual data from 1998-2018 with 20 samples (see Table 1).

ISSN: 2692-7608 DOI: 10.6981/FEM.202108_2(8).0023

Table 1. The original data.

Year	GDP/ 100 million yuan	CC/ 10,000 tons of standard coal	PC/ 10,000 tons of standard coal	NC/ 10,000 tons of standard coal	OC/ 10,000 tons of standard coal
1998	85195.5	96554.46	28326.27	2451.312	8851.96
1999	90564.4	99241.71	30222.34	2811.38	8293.571
2000	100280.1	100670.3	32332.08	3233.208	10728.37
2001	110863.1	105772	32975.96	3733.128	13065.95
2002	121717.4	116160.2	35611.17	3900.271	13905.31
2003	137422	138352.3	39219.52	4532.909	14978.31
2004	161840.2	161657.3	45825.92	5296.463	17501.36
2005	187318.9	189231.2	46523.68	6272.856	19341.31
2006	219438.5	207402.1	50131.73	7734.609	21198.56
2007	270092.3	225795.5	52945.14	9343.26	23358.15
2008	319244.6	229236.9	53542.04	10900.77	26931.32
2009	348517.7	240666.2	55124.66	11764.41	28570.71
2010	412119.3	249568.4	62752.75	14425.92	33900.91
2011	487940.2	271704.2	65023.22	17803.98	32511.61
2012	538580	275464.5	68363.46	19302.62	39007.39
2013	592963.2	280999.4	71292.12	22096.39	42525.13
2014	641280.6	279328.7	74090.24	24270.94	48116.08
2015	685992.9	273849.5	78672.62	25364.4	52018.51
2016	740060.8	270207.8	80626.52	27020.78	57963.93
2017	820754.3	270911.5	80735.22	31397.03	61897
2018	896915.6	273760	87696	36192	66352

In order to eliminate the influence of heteroscedasticity that may exist in the sequence, the experimental data is processed by logarithm of the original data, and the variables lnGDP, lnCC, lnPC, lnNC and lnOC are obtained. As shown in table 2:

Table 2. Logarithmic processing data.

Year	lnGDP	lnCC	lnPC	lnNC	Primary power and other energy
1998	11.3527	11.47786	10.25154	7.804379	9.088394
1999	11.41382	11.50531	10.31634	7.941431	9.023236
2000	11.51572	11.51961	10.38382	8.08123	9.280647
2001	11.61605	11.56904	10.40353	8.225002	9.477765
2002	11.70946	11.66273	10.48041	8.268801	9.540026
2003	11.83081	11.83756	10.57693	8.419119	9.614358
2004	11.99436	11.99323	10.73261	8.574795	9.770034
2005	12.14057	12.15072	10.74772	8.743987	9.869998
2006	12.29883	12.24241	10.82241	8.95346	9.961688
2007	12.50652	12.32738	10.87701	9.142411	10.0587
2008	12.67371	12.34251	10.88822	9.296589	10.20105
2009	12.76144	12.39117	10.91735	9.372834	10.26014
2010	12.92907	12.42749	11.04696	9.576782	10.4312
2011	13.09795	12.51247	11.0825	9.787177	10.38935
2012	13.19669	12.52621	11.13259	9.867996	10.57151
2013	13.29289	12.54611	11.17454	10.00317	10.65785
2014	13.37122	12.54014	11.21304	10.09704	10.78137
2015	13.43862	12.52033	11.27305	10.1411	10.85935
2016	13.51449	12.50695	11.29758	10.20436	10.96758
2017	13.61798	12.50955	11.29893	10.35447	11.03323
2018	13.70672	12.52001	11.38163	10.49659	11.10273

3. Empirical Research

3.1. Unit root test

In empirical research based on time series data, it is necessary to assume that the time series it is based on is stationary, because the non-stationary data will lead to the phenomenon of "false

ISSN: 2692-7608 DOI: 10.6981/FEM.202108_2(8).0023

regression" and the meaningless statistical tests, so it is necessary to test the stationarity of the data first, namely, the unit root test. Using Eviews to test the stationarity of the variables, the results (see Table 3) show that the original variables lnGDP, lnCC, lnPC, lnNC and lnOC time series are not stationary. Therefore, the first-order difference unit root test is carried out, and the results show that the first-order difference variable time series △lnGDP, △lnCC, △lnPC, △NC, △lnOC are also not stationary. The results show that their second-order difference variables △2GDP, △ 2LNCC, △ 2LNPC, △ 2LNNC, and △ 2LNOC are stationary, that is, the original variables are all second-order integral sequences, and the co-integration test can be performed.

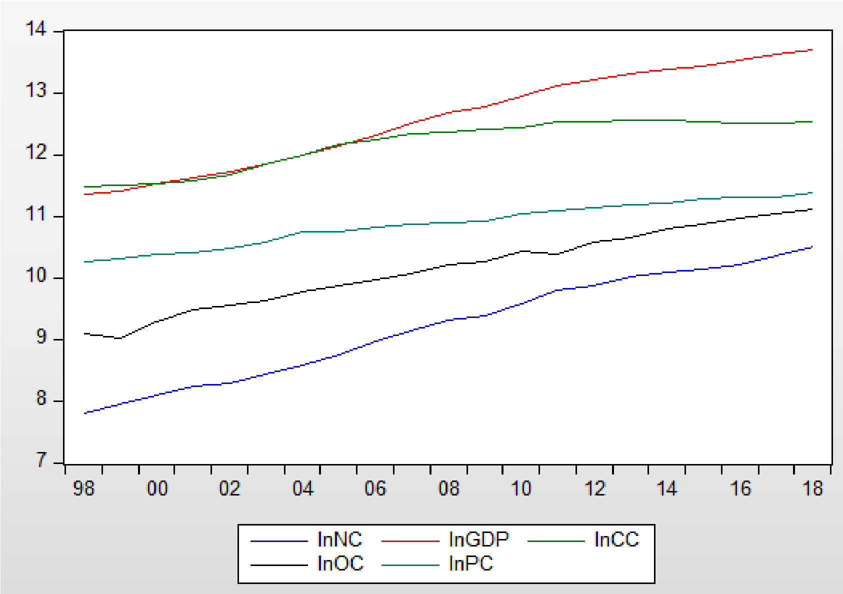

Figure 1. Stationary test diagram.

Table 3. Variable unit root test results.

Variable	ADF test value	Critical value(1%)	Conclusion
lnGDP	1.993001	-2.692358	non-stationary
△lnGDP	-0.548030	-2.699769	non-stationary
$△^2$lnGDP	-5.667096	-2.708094	stationary
lnCC	0.815099	-2.692358	non-stationary
△lnCC	-0.955610	-2.699769	non-stationary
$△^2$lnCC	-3.332301	-1.964418	stationary
lnPC	3.595154	-2.692358	non-stationary
△lnPC	-1.221865	-2.699769	non-stationary
$△^2$ lnPC	-5.105823	-2.708094	stationary
lnNC	2.686840	-2.692358	non-stationary
△lnNC	-0.674956	-2.699769	non-stationary
$△^2$lnNC	-4.945747	-2.708084	stationary
lnOC	5.837424	-2.692358	non-stationary
△lnOC	-1.312504	-2.699769	non-stationary
$△^2$lnOC	-7.102073	-2.708094	stationary

LNGDP is taken as an example to show the stationarity test results, as shown in Figure 2.

3.2. Test of the Co-integration Relationship between Energy Consumption and Economic Growth

If the time series under consideration have the same single integral order, and a certain linear combination (cointegration vector) reduces the single integral order of the combined time

ISSN: 2692-7608 DOI: 10.6981/FEM.202108_2(8).0023

series, it is said that there is a significant cointegration relationship between these time series. There are two commonly used methods to test whether there is a co-integration relationship between variables. One is the co-integration test based on regression coefficient, such as the Johansen-Juselius test. The other is co-integration test based on regression residuals, such as EG two-step method proposed by Engle and Granger. The JJ test method is a method of testing regression coefficients based on the VAR model. It is a method of multivariate cointegration test. The EG two-step method is suitable for single equation cointegration test. In view of the purpose of this article and the number of variables selected in the model, the EG two-step method is used for testing.

Null Hypothesis: D(LNGDP,2) has a unit root
Exogenous: None
Lag Length: 1 (Fixed)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.667096	0.0000
Test critical values:	1% level	-2.708094	
	5% level	-1.962813	
	10% level	-1.606129	

*MacKinnon (1996) one-sided p-values.
Warning: Probabilities and critical values calculated for 20 observations and may not be accurate for a sample size of 17

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(LNGDP,3)
Method: Least Squares
Date: 06/10/20 Time: 15:51
Sample (adjusted): 2002 2018
Included observations: 17 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LNGDP(-1),2)	-1.811968	0.319735	-5.667096	0.0000
D(LNGDP(-1),3)	0.560714	0.209032	2.682438	0.0170

R-squared	0.716653	Mean dependent var	-0.000775
Adjusted R-squared	0.697763	S.D. dependent var	0.061703
S.E. of regression	0.033922	Akaike info criterion	-3.819388
Sum squared resid	0.017260	Schwarz criterion	-3.721363
Log likelihood	34.46480	Hannan-Quinn criter.	-3.809644
Durbin-Watson stat	1.536624		

Figure 2. ADF test results of lnGDP.

Since the sequences lnGDP, lnCC, lnPC, lnNC, and lnOC are all second-order single integer sequences, it can be further tested whether there is a long-term cointegration relationship between them. Firstly, the static regression equations of lnGDP- lnCC, lnGDP-lnPC, lnGDP-lnNC, and lnGDP-lnOC are established respectively, and then the unit root test is performed on the residuals obtained by the static regression. The first step is to use the least square method to estimate the parameters and establish the regression equation between lnGDP and lnCC:

$$\ln CC = 6.134387 + 0.480365 * \ln GDP \quad (1)$$

$R^2 = 0.899448$ $\overline{R^2} = 0.894156$

Establish the regression equation between lnPC and lnGDP:

$$\ln PC = 5.282166 + 0.444630 * \ln GDP \quad (2)$$

$R^2 = 0.983746$ $\overline{R^2} = 0.982890$

ISSN: 2692-7608 DOI: 10.6981/FEM.202108_2(8).0023

Establish the regression equation between lnnc and lnGDP:

$$\ln NC = -4.500005 + 1.090436 * \ln GDP \tag{3}$$

$R^2 = 0.998731$ $\overline{R^2} = 0.998644$

Establish the regression equation between lnOC and lnGDP:

$$\ln OC = 0.042582 + 0.803266 * \ln GDP \tag{4}$$

$R^2 = 0.984114$ $\overline{R^2} = 0.983278$

As can be seen from Equations (1), (2), (3) and (4), the coefficients of coal consumption, oil consumption, natural gas consumption and other energy consumption on economic growth are 0.480365, 0.444630, 1.090436 and 0.803266 respectively, indicating that natural gas has the most significant impact on economic growth. In order to avoid the pseudo-regression phenomenon of the two variables in the equation, the unit root test should be carried out on the regression residual sequence of the above equation. If the regression residual sequence is stable, it can be shown that the two variables in the regression equation have a co-integration relationship. In this paper, ADF test is used to test the unit root of the regression residual sequence, and the results are shown in Table 4.

Table 4. Residual unit root test results.

Sequence	ADF test value	Critical value(5%)	Conclusion
Residual sequence CC	-1.445230	-1.959071	non-stationary
Residual sequence PC	-2.588300	-1.959071	stationary
Residual sequence NC	-3.845711	-1.950771	stationary
Residual sequence OC	-2.400844	-1.959071	stationary

The test results show that the residual sequence of the regression equation between oil consumption, natural gas consumption and other energy consumption and economic growth rejects the null hypothesis at the significance level of 5%. It indicates that the residual series is a stationary series, and the residual series of the regression equation between coal consumption and economic growth cannot reject the null hypothesis at a significant level of 5%. Therefore, there is a co-integration relationship between oil consumption, natural gas consumption and other energy consumption and economic growth.

3.3. Error correction model

The regression equation in the previous section only shows that there is a long-term equilibrium relationship between variables, which needs to be corrected for errors. A group of variables with cointegration relationship can always be represented by an error correction model, which mainly reveals the short-term unbalanced relationship between variables. According to the regression equation (1) of oil consumption and economic growth, an error correction model is established.

$$\Delta \ln PC = 0.486911 \Delta \ln GDP - 0.457375 ecm_{t-1} \tag{5}$$

The above error correction model describes the dynamic influence of equilibrium error on economic growth, and the error correction coefficient is -0.457375, which conforms to the reverse correction mechanism. According to the error correction model, the short-term dynamic equilibrium relationship between the two is as follows: oil consumption changes 0.486911 units for every 1 unit change in economic growth in the short term. The error correction factor is 0.457375, indicating that the average annual short-term adjustment of oil consumption from the long-term equilibrium level of the previous year is 45.7375%.

According to the regression equation (2) of natural gas consumption and economic growth, an error correction model is established:

ISSN: 2692-7608 DOI: 10.6981/FEM.202108_2(8).0023

$$\Delta \ln NC = -0.051324\Delta \ln NC_{t-1} + 1.328434\Delta \ln GDP - 0.165488\Delta \ln GDP_{t-1} - 0.082121 ecm_{t-1} \quad (6)$$

The error correction model coefficient of natural gas consumption and economic growth is -0.082121, which conforms to the reverse correction mechanism. According to the error correction model, the short-term equilibrium relationship between the two is as follows: economic growth changes by 1 unit in the short term, and natural gas consumption changes by 1.328434 units. The error correction factor is -0.082121, indicating that the average annual short-term adjustment of natural gas consumption from the long-term equilibrium level of the previous year is 8.2121%.

According to the regression equation (3) of other energy consumption and economic growth, an error correction model is established:

$$\Delta \ln OC = 0.817266\Delta \ln GDP - 0.373282 ecm_{t-1} \quad (7)$$

The coefficient of error correction model between other energy consumption and economic growth is -0.373282, which conforms to the reverse correction mechanism. From the perspective of the error correction model, the short-term equilibrium relationship between the two is that economic growth changes by 1 unit in the short term, while other energy consumption changes by 0.817266 units. This value is smaller than the value of the long-term equilibrium regression equation, which also indicates that economic growth has a more significant long-term impact on other energy consumption. The error correction coefficient is -0.373282, indicating that the average annual short-term adjustment range of other energy consumption in China is 37.3282% from the long-term equilibrium level in the previous year.

3.4. Granger causality test

According to the above co-integration test results, there is a long-term co-integration relationship between oil consumption, natural gas consumption and other energy consumption and economic growth, but whether this equilibrium relationship constitutes a causal relationship still needs further verification. Because the Granger causality test is very sensitive to lag order, this paper selects 1, 2 and 3 as lag order to analyze the three groups of variables respectively. The results of Granger causality test on variables are shown in Table 5.

Table 5. Granger causality test.

lag	Null hypothesis	F value	P value	Decision
1	LNPC is not the Granger cause of LNGDP	14.0158	0.0016	Reject
	LNGDP is not the Granger cause of LNPC	0.52894	0.4770	Accept
2	LNPC is not the Granger cause of LNGDP	1.81007	0.1999	Accept
	LNGDP is not the Granger cause of LNPC	0.36871	0.6981	Accept
3	LNPC is not the Granger cause of LNGDP	2.69255	0.0975	Accept
	LNGDP is not the Granger cause of LNPC	0.36451	0.7800	Accept
1	LNNC is not the Granger cause of LNGDP	0.65877	0.4282	Accept
	LNGDP is not the Granger cause of LNNC	1.39354	0.2541	Accept
2	LNNC is not the Granger cause of LNGDP	0.34580	0.7135	Accept
	LNGDP is not the Granger cause of LNNC	3.14808	0.0443	Reject
3	LNNC is not the Granger cause of LNGDP	2.69255	0.0975	Accept
	LNGDP is not the Granger cause of LNNC	0.36451	0.7800	Accept
1	LNOC is not the Granger cause of LNGDP	1.54481	0.2308	Accept
	LNGDP is not the Granger cause of LNOC	2.58651	0.1262	Accept
2	LNOC is not the Granger cause of LNGDP	1.22520	0.3233	Accept
	LNGDP is not the Granger cause of LNOC	3.60200	0.0447	Reject
3	LNOC is not the Granger cause of LNGDP	1.43990	0.2840	Accept
	LNGDP is not the Granger cause of LNOC	2.45411	0.1180	Accept

ISSN: 2692-7608 DOI: 10.6981/FEM.202108_2(8).0023

4. Conclusion

There is a long-term equilibrium relationship between coal consumption, oil consumption, natural gas consumption and other energy consumption and economic growth. Economic growth has different effects on different types of energy consumption. From the perspective of the long-term equilibrium relationship, natural gas consumption has a significant impact on China's economic growth.

At the current stage of our country, there is a dilemma not only to ensure economic development but also to control carbon emissions. It is recommended to solve this dilemma from the following aspects.

(1) The government adjusts the energy structure rationally through macroeconomic regulation. The government adopts certain fiscal and monetary policies to guide the rational allocation of social resources, promote the development of low energy consumption and clean energy industries, and promote the application of clean energy such as wind power, hydropower, and nuclear power in various industrial production.

(2) Improve the level of energy utilization. The government should strengthen the dissemination and promotion of energy information through multiple channels, and improve the technological level of energy enterprises through a combination of independent innovation and absorption.

(3) Develop a low-carbon economy. High-speed economic growth inevitably brings high carbon emissions, which will gradually decline as economic growth slows down. However, in order to reduce carbon emissions, we should not sacrifice economic growth at the expense of the development of low-carbon economy.

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