Developing Country Studies
ISSN 2224-607X (Paper) ISSN 2225-0565 (Online)
Vol.5, No.14, 2015

The Relationship between Energy Input and Economic Development: Latest Evidence from China

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The research is supported by the Major Program of National Natural Science Foundation of China (No. 41401188), the Youth Program of National Natural Science Foundation of China (No. 71203233) and National Energy Administration (No. 201312). This article is published on July 31, 2015.

Abstract
China's energy consumption, energy production and economic production have all experienced fast growth over the past few decades. Previous research suggests a possible causal relationship between economic growth and energy consumption, but no enough empirical evidences were provided. Therefore, this research intends to evaluate the relationship between energy input and economic development, using China's latest data and by means of elasticity and statistical tests. Conclusions drawn from the results suggest that there is a varying positive correlation between energy and economic development; China's energy efficiency has improved while the dependency of China's economy on electricity has increased in recent years; there is a unidirectional causality from economic growth to energy consumption and a unidirectional relationship from economic growth to coal consumption. This paper provides comprehensive information on the relationship between China's energy input and economic development, which can be useful for policy makers and researchers.
Keywords: Energy consumption, Economic development, Causality

1. Introduction

Energy, as an essential factor of production, the development of economy is closely related to it. Energy is used in every aspect of economic activity, such as mining, transportation, processing and so on. On the one hand, energy acts as the power source of economic growth providing fuels for cooking, vehicles, machines and etc. Moreover, some energy resources such as coal and oil are basic materials of production for manufacturing industries. Therefore, energy constitutes an important factor in economic growth. On the other hand, the larger the scale of production grows, the more energy will be required to support the production. At the same time, as the income level increases, energy use in the residential sector also expands quickly due to the improvement of living status and consumption of more goods. It is no doubt that, the production and live in the modern society cannot maintain without energy, and the sustainable development of economy and society largely depends on energy resources.

The relationship between energy input and economic development has strong implications for energy and growth policy. Theoretically, energy input can boost economic growth, while economic growth can drive up energy input. In other words, there is a possible causal relationship between energy input and economic development. Scholars tried to provide empirical evidences with data from different countries and various methods. For example, Yoo and Kwak (2010) studied the causal relationship between electricity consumption and economic growth using data from seven South American countries(Argentina, Brazil, Chile, Columbia, Ecuador, Peru, and Venezuela) during 1975 to 2006. They found that the causal nexus between electricity consumption and economic growth varied across countries: a unidirectional causality from electricity consumption to real GDP for Argentina, Brazil, Chile, Columbia, and Ecuador; a bidirectional causality in Venezuela and no causal relationships in Peru. Chinese scholars Wang, Tian and Jin (2006) evaluated the relationship between China's economic growth and energy consumption by applying the state space model to China's data from 1953 to 2002. Their conclusion was that a long-run equilibrium relationship existed between China's economic growth and energy consumption. However, the relationship is not constant. Instead, it evolved over time. Wang and Liu (2007) proposed a unidirectional relationship from energy consumption to economic growth in China during 1978 to 2005; on the contrary, Lin, Wei and Li (2007) discovered a unidirectional relationship from economic growth towards the major energy resource i.e. coal consumption for the almost overlapping period from year 1980 to 2004.

The previous studies definitely provide valuable information, but their results are controversial. As a result, the relationship between China's energy input and economic development has not yet been determined. In addition, this relationship may change throughout the time. Therefore, this study aims to investigate the relationship between China's energy input and economic development, drawing on the most recent data. The structure of this research is as follows. Section 2 describes the evolution paths of energy consumption and economic development from 1995. Section 3 discusses both the relationship between economic growth and energy

consumption and the relationship between economic growth and energy production by means of elasticity. Section 4 investigates the causal nexuses by applying Granger-causality tests. Finally, conclusions are drawn based on previous analyses.

2. Review of China's energy consumption and economic development

According to National Bureau of Statistics of the People's Republic of China, China's energy consumption and gross domestic product (GDP) were respectively 1312 million tons of standard coal and 6113 billion RMB in 1995. Since then, China's GDP has grown rapidly all the way, without any setback even during the two financial crises (year 1997 and 2008), to 58802 billion RMB in 2013 which is approximately three times of that in 2005 and ten times of that in 1995. The average yearly growth rate of GDP reaches 13.5% and the growth rate is higher than 10% for most of the years. Meanwhile, China's total energy consumption has almost tripled since 1995, amounting to 3750 million tons of standard coal in 2013. Energy consumption has also grown rapidly, particularly after 2000, with the average yearly growth rate of around 7.9%. The co-evolution path of GDP and energy consumption are shown in figure 1. As can be seen, the growth rates of energy consumption and GDP usually move in the same direction over the years.

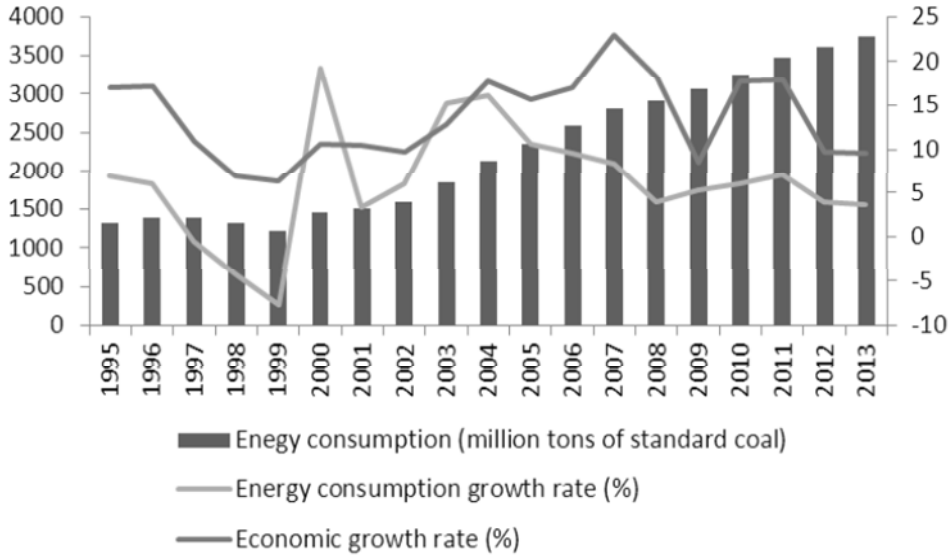

Figure 1. The trends of energy consumption and economic growth since 1995

As for the energy consumption structure, there are no major changes in China's primary energy consumption structure during the last three decades (See Figure 2). In China's primary energy consumption structure, coal took the absolute dominant position, constantly accounting for about 70% share of the total energy consumption. In recent years, the share of natural gas consumption has grown from 1.8% in 1995 to 5.8% in 2013 while the share of other carbon-intense fusil-fuels has slightly declined (coal 66%, oil 18.4%). From the perspective of final energy use, the end use of coal has increased from only around 200 million tons of standard coal in 1980 to 769 million tons in 2012, while the share of coal in total final energy use has declined from 40.8% to 32.7%. On the other hand, the share of oil, natural gas and electricity consumption has significantly went up: the consumption of oil from 53 million tons (10.8% of the total) to 608 million tons of standard coal (24.8%), natural gas from 2 million tons (1.1%) to 116 million tons of standard coal (5.8%), and electricity from 3.0% to 21.0%.

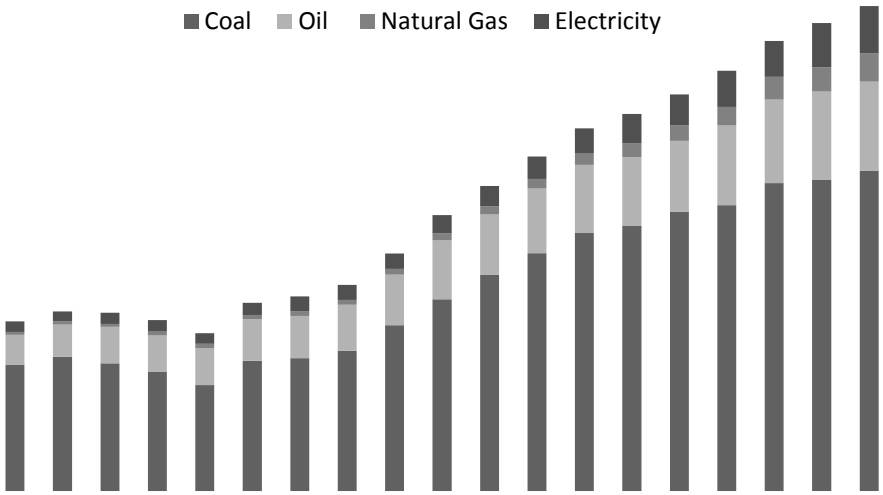

Figure 2. The structure of energy use since 1995 unit: million tons of standard coal

3. The relationships of energy and electricity with economic development

Elasticity measures the responsiveness of one variable to the change of one influencing variable. That is to say, elasticity ratio of energy production measures the responsiveness of energy production to the change in economic output as represented by GDP. Similarly, elasticity ratio of electricity production measures the responsiveness of electricity production to the change in GDP. Likewise, elasticity ratio of energy consumption and elasticity ratio of electricity consumption indicate the responsiveness of energy consumption and electricity consumption to the change in GDP respectively. All four elasticity ratios over the years can be found on the webpage of National Bureau of Statistics of the People's Republic of China and are reported in table 1.

Table 1. Elasticity ratios of energy production/consumption over the years

year	Elasticity ratio of energy production	Elasticity ratio of electricity production	Elasticity ratio of energy consumption	Elasticity ratio of electricity consumption
1995	0.83	0.82	0.66	0.78
2000	0.28	1.12	0.42	1.13
2001	0.79	1.11	0.4	1.12
2002	0.52	1.29	0.66	1.3
2003	1.41	1.55	1.53	1.56
2004	1.43	1.51	1.6	1.52
2005	0.88	1.19	0.93	1.19
2006	0.58	1.15	0.76	1.15
2007	0.46	1.02	0.59	1.01
2008	0.56	0.58	0.41	0.58
2009	0.59	0.77	0.57	0.78
2010	0.78	1.28	0.58	1.27
2011	0.76	1.29	0.76	1.3
2012	0.57	0.75	0.51	0.77

Source: National Bureau of Statistics of the People's Republic of China, link: http://www.stats.gov.cn/tjsj/ndsj/.
Note: Elasticity ratios of energy production or consumption are calculated by dividing the annual growth rate of energy production or consumption with the annual growth rate of GDP; Elasticity ratios of electricity production or consumption are calculated by dividing the annual growth rate of electricity production or consumption with the annual growth rate of GDP.

As can be seen from Table 1, the elasticity ratios are all positive in signs, indicating the positive

correlation of energy and economic development. The values of the four elasticity ratios vary and fluctuate over the years. Specifically, the elasticity ratio of energy production is 0.57 in 2012, which can be interpreted as that energy production will grow by 0.57 percent for each percent of growth in GDP. The elasticity ratio of energy production reaches its peak around 2004, with the value of over 1.4, which reveals that energy production has experienced quick development, even exceeding the economic growth. Moreover, elasticity ratio of electricity production is almost always larger than that of energy production, greater than 1 for most of the years, which shows that the power sector has expanded rapidly in China, constantly ahead of the economic growth.

On the other hand, the elasticity of energy consumption has varied a lot over the years while electricity consumption has generally been quite elastic, with ratios greater than 1 for most of the years. Both the elasticity of energy consumption and elasticity of electricity consumption reach their peaks around 2004. Then, the elasticity ratio of energy consumption has declined steadily. In 2012, the elasticity ratio of energy consumption is 0.51 which means that one percent of growth in GDP results in only 0.51 percent of energy consumption growth. In other words, the energy input needed for additional production has declined and China's economic production efficiency has been improved. However, the consumption of electricity has grown faster in recent years, reflecting the increasing dependency of China's economy on electricity.

4. Causality between energy consumption and economic growth

The Granger causality test, first proposed by Clive Granger in 1969, is a useful statistical hypothesis test to determine whether two variables have causal relationships. In terms of time serial variables, for example, one variable is said to Granger cause another variable if adding lagged values of the explanatory variable can generate significantly better prediction for future values of the dependent variable than using past values of the dependent variable alone (Granger, 1969). In short, that is to say, prior values of one variable can predict future values of another variable. The null hypothesis of Granger causality test is no Granger causality, thus the rejection of null hypothesis supports the Granger causal relationship, which can be determined from P-values.

Granger causality tests between energy consumption growth and economic growth and between coal consumption growth and economic growth are to be performed for the period from year 1995 to 2013. Let G stand for the economic growth rate, Eg for energy consumption growth rate and Cg for coal consumption growth rate. It is worth noted that Granger causality tests should not be applied to non-stationary time serial variables. To avoid spurious causality tests, unit-root tests have been conducted for G, Eg and Cg to determine whether these variables are stationary. Two types of unit-root tests have been performed (See Table 2), i.e. Augmented Dickey-Fuller unit-root test and the Phillips-Perron unit-root test. Results suggest that P-values of G, Eg and Cg are respectively 0.0503, 0.0181, 0.0015. In other words, P-values of Eg and Cg are clearly significant at 5% level, while the P-value of G is clearly significant at 10% level and almost significant at 5% level. Therefore, all three variables are found to be stationary and Granger causality tests can be safely trusted.

Table 2. Results of unit root tests

	Augmented Dickey-Fuller method		Phillips-Perron method	
Variable	Test statistics	P-value	Test statistics	P-value
G	-2.859	0.0503	-2.804	0.0577
Eg	-3.234	0.0181	-3.230	0.0183
Cg	-3.976	0.0015	-4.114	0.0009

The results of Granger causality tests are shown in Table 3. As can be seen, the P-value of no Granger causality from economic growth to energy consumption growth is 0.093, which is significant at 10% level. Therefore, the null hypothesis should be rejected. It can be said that economic growth Granger causes energy consumption growth. On the other hand, the P-value of no Granger causality from energy consumption growth to economic growth is 0.277, which means that the null hypothesis cannot be rejected at 10% significance level. Thus, it suggests that energy consumption growth does not Granger cause economic growth. Moreover, the P-value of no Granger causality from economic growth to coal consumption growth is around 0.1, while the P-value of no Granger causality from coal consumption growth to economic growth is 0.488. Basically, it can be concluded that there is a unidirectional causal relationship from economic growth to coal consumption growth, but not the other way round.

Table 3. Results of Granger causality tests

Null hypothesis	Degree of freedom	Chi2-value	P-value	Reject or Accept
G→Eg	2	4.741	0.093	Reject
Eg→G	2	2.564	0.277	Accept
G→Cg	2	4.405	0.111	Reject
Cg→G	2	1.436	0.488	Accept

5. Conclusions

As is shown in the previous analyses, China's energy consumption and gross domestic product have both grown rapidly for the last two decades. Coal is the dominant energy source while electricity is playing an increasingly important role. The elasticity ratios are positive and vary over the years, which suggest a changeable positive correlation between energy input and economic development. Specifically, energy production and especially electricity have been elastic to economic growth for many years; energy use for additional production has declined in recent years indicating the improvement of efficiency while the dependency of China's economy on electricity has grown. Moreover, Granger causality tests find a unidirectional causal relationship from economic growth to energy consumption growth and from economic growth to coal consumption growth. As no causality is found from energy consumption growth to economic growth, it seems possible to realize environmental-friendly economic development by promoting technological innovations and energy efficiency. It should be noted that the sample covers only 19 years; as a result, significance levels of Granger causality tests have been compromised. If the sample size is enlarged, the conclusions should remain unchanged while the significance will be improved.

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