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Energy consumption-economic growth relationship and carbon dioxide emissions in China

Fei Li[a,*], Suocheng Dong[a], Xue Li[a], Quanxi Liang[b], Wangzhou Yang[a]

[a] Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China
[b] Jinan University, Guangzhou 510632, China

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ABSTRACT

This paper applies the panel unit root, heterogeneous panel cointegration and panel-based dynamic OLS to re-investigate the co-movement and relationship between energy consumption and economic growth for 30 provinces in mainland China from 1985 to 2007. The empirical results show that there is a positive long-run cointegrated relationship between real GDP per capita and energy consumption variables. Furthermore, we investigate two cross-regional groups, namely the east China and west China groups, and get more important results and implications. In the long-term, a 1% increase in real GDP per capita increases the consumption of energy by approximately 0.48–0.50% and accordingly increases the carbon dioxide emissions by about 0.41–0.43% in China. The economic growth in east China is energy-dependent to a great extent, and the income elasticity of energy consumption in east China is over 2 times that of the west China. At present, China is subject to tremendous pressures for mitigating climate change issues. It is possible that the GDP per capita elasticity of carbon dioxide emissions would be controlled in a range from 0.2 to 0.3 by the great effort.

1. Introduction

The using of fossil energy becomes the symbol of modern industrial civilization. However, greenhouse gas emissions have increased constantly because of human activity and fossil fuel combustion, which could significantly influence the internal balance process of global natural ecosystem. Meanwhile, energy shortage problem is increasingly serious due to overexploitation and abuse of the fossil energy. The climate change and energy problem deeply threaten the sustainable existence and development of all humankind. It has become the common standpoint of countries worldwide to address climate change, reduce carbon dioxide emissions and implement sustainable development stratagem.

Since the introduction of reform and an open-door policy, China has experienced rapid economic growth. The consumption of primary energy has also been increasing continuously, even with an annual growth rate of 10.9% during the 2003–2007 periods. The total energy consumption amount has magnified by approximately 3.5 times from 7.67×10^8 tons of SCE in 1992 to 26.56×10^8 tons of SCE in 2007, accordingly one-off energy consumption including coal, crude oil and natural gas had a rising trend wholly. The coal consumption in China accounts for approximately 69.5% of the total primary energy consumption in 2007 and 70.7% in 1978, only decreased by about 1.2%, which is over 4 times more than the average level in developed countries. The development of hydroelectric power, nuclear power and wind power is slow, rose by only 3.9% from 3.4% of the total energy consumption in 1978 to 7.3% in 2007 (see Table 1). Now the coal consumption results in about 70% of the soot dust emissions and 90% of the carbon dioxide emissions. With the low efficiency of energy use, the pattern of extensive economic growth and the backward management mode, the energy consumption per unit of GRP is too high. China is confronted with double challenges—addressing climate change in the international society and environmental protection with domestic economic transition.

The relationship between energy consumption and economic growth, which is studied by many authors using various methodologies for different time periods since the pioneering work of Kraft and Kraft (1978), becomes key and hot topic in environmental science, climatology and other relative academic fields. To test for a long-run relationship, the cointegration technique developed by Engle and Granger (1987) has been used in many researches within the last two decades, which was firstly used to study power demand in America by Engle et al. (1989), thereafter has become the mainstream method for studying the relationship between the two variables in a large amount of empirical researches. This relationship has been the focus of numerous theoretical explorations as well as a large number of empirical investigations (see for example, Erol and Yu, 1987; Stern, 1993, 2000; Masih and Masih,

* Corresponding author. Tel.: +86 15011357181; fax: +86 1064854230.
E-mail address: lfly2004@yahoo.com.cn (Fei).

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Table 1
Total consumption of energy and its composition from 1985 to 2007.
Sources: China Statistical Yearbooks, various years.

Year	Total energy consumption (10 000 tons of SCE)	As percentage of total energy consumption (%)			
		Coal	Crude oil	Natural gas	Hydro-power, nuclear power and wind power
1985	76682	75.8	17.1	2.2	4.9
1986	80850	75.8	17.2	2.3	4.7
1987	86632	76.2	17.0	2.1	4.7
1988	92997	76.2	17.0	2.1	4.7
1989	96934	76.0	17.1	2.0	4.9
1990	98703	76.2	16.6	2.1	5.1
1991	103783	76.1	17.1	2.0	4.8
1992	109170	75.7	17.5	1.9	4.9
1993	115993	74.7	18.2	1.9	5.2
1994	122737	75.0	17.4	1.9	5.7
1995	131176	74.6	17.5	1.8	6.1
1996	138948	74.7	18.0	1.8	5.5
1997	137798	71.7	20.4	1.7	6.2
1998	132214	69.6	21.5	2.2	6.7
1999	133830.97	69.09	22.57	2.14	6.2
2000	138552.58	67.75	23.21	2.35	6.69
2001	143199.21	66.68	22.87	2.55	7.9
2002	151797.25	66.32	23.41	2.56	7.71
2003	174990.3	68.38	22.21	2.58	6.83
2004	203226.68	67.99	22.33	2.6	7.08
2005	224682	69.1	21.0	2.8	7.1
2006	246270	69.4	20.4	3.03	7.2
2007	265583	69.5	19.7	3.5	7.3

1998; Oh and Lee, 2004a, b; Ghali and El-Sakka, 2004; Beaudreau, 2005; for some recent studies on developing countries, e.g. Glasure, 2002; Lee, 2005; Chen et al., 2007; Mahadevan and Asafu-Adjaye, 2007; Squalli, 2007; Akinlo, 2008; Chontanawat et al., 2008; Lee and Chang, 2007,2008; Narayan and Smyth, 2009; Wolde-Rufael, 2009), which is researched mainly based on one of two perspectives: the time series econometric analysis and the dynamic panel data approach. The previous test results have mostly been based on individual city or country using time series data (See for example in China, Han et al., 2004; Wang et al., 2006; Zhong et al., 2007). However, non-stationarity in the time series was not taken into account in some researches, and the cointegration relationship should also be further tested for the limitations in the relatively small available time series sample. (See as Stern, 1993, 2000 and Oh and Lee, 2004a, b) Hence, studies that have tested the relationship between these two variables reveal conflicting results on the issue, mainly due to the fact that estimation results are very sensitive to the time period considered, the region and the methodology employed. Some recent studies have also employed the panel data approach to investigate the energy-economy nexus in both developed and developing countries (see for example, Huang et al., 2008; Narayan et al., 2007; Mahadevan and Asafu-Adjaye, 2007; Narayan and Smyth, 2007, 2008, 2009; Lee et al., 2008; Apergis and Payne, 2009; Sadorsky, 2009). In China, Yu and Meng (2008) and Wu et al. (2008) researched the relation using the provincial panel data, respectively. Xu and Pan (2009) investigated the six industrial sector data. Though employing the panel data approach, the cointegrated relationship among variables was neglected by some authors (See as Olatubi and Zhang, 2003), and the accuracy of OLS estimation and FMOLS estimation were also affected for small available dataset sample. In addition, elastic coefficients calculated were not in accordance with practice in some literatures.

The energy consumption-economic growth relation analysis, which is related to not only timing sequence dimensions, but also to cross-section dimensions, needs to be examined using econometrics strictly and carefully. Consideration of data properties is necessary because appropriate methods depend on whether data is stationary for time series. If there is no cointegration in a posited regression among non-stationary variables, the regression could be spurious, and interpreting the results in the classical way would be invalid. Furthermore, the panel data can provide much more information than either cross-sectional data or time series, and in light of the lack of power of individual unit root tests and traditional cointegration tests, the combined information from time series and cross-sectional data is needed. Harris and Tzavalis (1999) determined that these panel tests allow for both parameter and dynamic heterogeneity across groups, and that they are considerably more powerful than conventional tests. Instead of following a time series or traditional panel data approach to prevent further debate, we use a new heterogeneous panel cointegration technique to re-investigate the relationship between energy consumption and economic growth across 30 Chinese provincial economies from 1985 to 2007. Then we use the dynamic ordinary least squares (DOLS) technique to estimate the cointegration vector for heterogeneous cointegrated panels. This enables us to correct the standard OLS for bias induced by endogeneity and serial correlation of the regressors. When compared with the previous approach, it is a more powerful tool and allows us to increase the degrees of freedom. Finally, we explore different group issues that are of concern to the east China and the west China, and with the results of this study, we are able to examine the deeper characteristics that determine the most efficient policies with respect to energy consumption.

2. Data description and definition of the variables

We use the annual time series data from 30 provinces and municipalities (The data for Tibet are not available for most years) in mainland China. The sample includes Beijing, Tianjin, Hebei, Shanxi, Inner Mongolia, Liaoning, Jilin, Heilongjiang, Shanghai, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Shandong, Henan, Hubei, Hunan, Guangdong, Guangxi, Hainan, Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang,