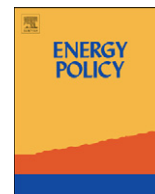




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## Energy consumption and economic growth in China: A multivariate causality test

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## ABSTRACT

This study takes a fresh look at the direction of causality between energy consumption and economic growth in China during the period from 1972 to 2006, using a multivariate cointegration approach. Given the weakness associated with the bivariate causality framework, the current study performs a multivariate causality framework by incorporating capital and labor variables into the model between energy consumption and economic growth based on neo-classical aggregate production theory. Using the recently developed autoregressive distributed lag (ARDL) bounds testing approach, a long-run equilibrium cointegration relationship has been found to exist between economic growth and the explanatory variables: energy consumption, capital and employment. Empirical results reveal that the long-run parameter of energy consumption on economic growth in China is approximately 0.15, through a long-run static solution of the estimated ARDL model, and that for the short-run is approximately 0.12 by the error correction model. The study also indicates the existence of short-run and long-run causality running from energy consumption, capital and employment to economic growth. The estimation results imply that energy serves as an important source of economic growth, thus more vigorous energy use and economic development strategies should be adopted for China.

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## 1. Introduction

In the past three decades the relationship between energy consumption and economic growth on a national and international level has been a well studied topic (Ang, 2008; Oh and Lee, 2004b), initially motivated by concerns about the security of energy supply (Bohi and Zimmerman, 1984) and later in view of additional concerns about the effects of greenhouse gas emissions on global warming (Hu and Lin, 2008). As for China's energy consumption since the beginning of the 2000s, the average growth in electricity consumption has been 8.8%, which is close to the real GDP growth of 10.4% over the same period. The purpose of this paper is to determine whether there is a stationary, long-run equilibrium relationship between energy consumption and real GDP for China, and to re-examine multivariate causality between these variables, employing the bounds testing approach to cointegration, within an autoregressive distributed lag (ARDL) framework suggested by Pesaran (Pesaran and Shin, 1999; Pesaran et al., 2001). From a policy viewpoint, the direction of causality between these variables shall have a significant bearing upon policy (Asafu-Adjaye, 2000; Ghosh, 2002; Narayan

and Prasad, 2008; Narayan and Smyth, 2005; Yoo, 2005). If a finding in favor of a positive unidirectional Granger causality runs from economic growth or labor force to energy consumption or if there is no causality in either direction, this implies that energy conservation policies would not have adverse effect economic growth. However, if unidirectional causality runs from energy consumption to economic growth or labor force, then reducing electricity consumption could lead to a fall in economic growth.

The contribution of our empirical study is twofold. First, to remedy econometric issue in estimation due to the omission of relevant variables, this study employs a multivariate causality test by incorporating capital and labor variables into the model between energy consumption and economic growth. Second, this study employs the ARDL bound testing approach of cointegration, as it should be shown to have better small-sample merit than existing cointegration tests. These two developments will potentially produce more precise and reliable results and hence will provide viable policy implication on energy use and economic development derived from our study.

The remainder of this paper is organized as follows: Section 2 provides a brief overview of the related literature; Section 3 describes the model, econometric methodology and data used in the study; Section 4 presents the unit root test results, the cointegration results and vector error correction model and

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Granger causality test results, followed by policy analysis in Section 5 and finally the conclusions.

## 2. Literature review

Given that the motivation for probing the direction of causation between energy consumption and economic growth has important implications from theoretical, empirical and policy standpoints, considerable literature exists. Relevant studies on the relationship between energy consumption and economic growth can be traced to the seminal work of Kraft and Kraft (1978) for the United States, and later extend to include industrial countries and regions such as the United Kingdom, Germany, Italy, Canada, France, Japan and Greece (Abosedra and Baghestani, 1989; Akarca and Long, 1980; Erol and Yu, 1987; Yang, 2000; Yu and Choi, 1985; Yu and Hwang, 1984). However, empirical evidence from these studies seems to be divergent rather than convergent (Hu and Lin, 2008; Oh and Lee, 2004b). The lack of consensus may be largely due to the differences in the development stages of the various countries studied or the differences in the data and the methodologies employed (Soytas and Sari, 2006b).

In the subsequent studies, the cointegration and Vector Error Correction Model (VECM) technique with a bivariate (Lise and Van Montfort, 2007; Masih and Masih, 1996; Shiu and Lam, 2004; Soyta and Sari, 2003; Yuan et al., 2007; Zachariadis, 2007) or multivariate (Ghali and El-Sakka, 2004; Masih and Masih, 1997; Oh and Lee, 2004a; Soyta and Sari, 2007) methodology are applied to explain the causal relationship between energy consumption and economic growth. Rather than a vector autoregressive (VAR) method in the presence of cointegration among variables, a VECM can distinguish between a long run and a short-run relationship among the variables, and can identify sources of causation that cannot be detected by the usual Granger causality test (Oh and Lee, 2004b). Moreover, a common view in the literature now is that studies on bivariate model may be biased due to the omission of relevant variables (Narayan and Smyth, 2005; Stern, 2000). Thus, recent research in this area has tended to treat energy as an essential factor in economic activities and investigate the energy-output Granger causality in multivariate framework, which includes two perspectives: the demand side (or energy demand function) and the production side (or the aggregate production function) (Lee and Chang, 2008). On the demand side, Masih and Masih (1997) and Asafu-Adjaye (2000) examined the relationship with a trivariate model by adding consumer price index (CPI) as a proxy for the real energy price variable to the conventional energy-GDP bivariate model. Oh and Lee (2004b) also looked at the relationship by using real energy price instead CPI (with three variables, namely energy, GDP and real energy price instead CPI). The production side model, however, takes energy, capital, and labor as separate inputs to be tested in a neo-classical aggregated production framework. Following this framework, Stern (1993, 2000) investigated Granger causality between energy and GDP in a production model for the USA in the post-war period. Oh and Lee (2004a) also looked at the relationship for Korea, employing a vector error correction technique (VECM). Ghali and El-Sakka (2004) found bilateral causality between energy use and output for Canada. Soyta and Sari (2003) found unidirectional causality running from total energy consumption to GDP for Turkey. Soyta and Sari (2007) also assumed a neo-classical production for Turkish manufacturing industry. The empirical research continued with Warr and Ayres (2010) re-examining the US energy-GDP relationship, Tsani (2010) exploring the Greek energy-GDP relationship and Wolde-Rufael and Menyah (2010) investigating the nuclear energy-GDP

relationship in nine developed countries. However, results from multivariate studies have also been mixed and remain ambiguous. One possible reason for the lack of consensus in multivariate studies on the same countries may be the arbitrary choice of control variables (Soytas and Sari, 2006b). Moreover, in a summary of the previous studies in the area, the residual-based cointegration test associated with Engle and Granger (1987) and the maximum likelihood test based on Johansen (1988) and Johansen and Juselius (1990) could be found to be widely used to determine the cointegration relationship among the variables (Odhiambo, 2009). These cointegration techniques may not be appropriate when the sample size is too small. However, small sample size is a common problem in such studies, especially for developing countries.

In recent studies, the bounds testing approach to cointegration, within an autoregressive distributed lag (ARDL) framework has become popular method pertaining to the causal relationship, since it has the advantage on better small sample properties than other popular methods of cointegration (Narayan and Smyth, 2005). Narayan and Smyth (2005) examined the relationship for Australia during the period 1969–1999 in trivariate framework (GDP, employment, electricity consumption). They found that in the long-run employment and real GDP Granger caused electricity consumption, while in the short-run there is weak unidirectional Granger causality running from GDP to electricity consumption and from GDP to employment. Following this framework, Narayan and Singh (2007) also looked at the electricity consumption and GDP nexus for the Fiji Islands and found that in the long-run causality runs from electricity consumption and labor force to GDP. Other recent empirical research includes Tang (2008), who re-examined the residential demand for electricity in the US economy; Ghosh (2009a), who explored the relationship between electricity supply, employment and real GDP in India for the time span 1970–1971 to 2005–2006; Chandran's (2010) modeling of the nexus between the variables in Malaysia during the period 1971–2003, and Odhiambo's (2009) investigation of the relationship between energy consumption and economic growth in Tanzania during the period 1971–2006.

While there are several studies that have investigated the causal relationship between energy consumption and economic growth using a production function framework for developed and some developing countries, such research is conspicuously lacking in insufficiency for China. It appears that only Yuan et al. (2008) investigated the relationship of the variables of capital, labor force, energy consumption and real GDP for China, using fixed assets of all industrial enterprises as a proxy for capital. The production model in this paper uses capital stock instead of fixed assets of all industrial enterprises for unbiased and consistent estimates, which differs from the study of Yuan et al. (2008). This empirical study also differs from Yuan et al. (2008) in its methodology. It employs recently developed ARDL bound testing approach of cointegration in preference to the cointegration test used by Engle and Granger (1987) and Johansen and Juselius (1990) for the reason that the bounds test has better small sample merit and can produce robust results in a short data span.

China has been on the track in the development process of rapid urbanization and industrialization. Not only the development stage and development process but also energy consumption patterns have significantly impact on energy and economic growth nexus in China. Therefore, the topic of the relationship between energy consumption and economic growth in China is of worldwide concern in both policy and scholarly circles. Following the development in this area, this paper investigates the direction of causality between energy consumption and economic growth in China over a thirty year period. A multivariate, production side model is constructed using energy, capital and labor as separate

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