Can China contribute more to the fight against global warming?

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Abstract

The greenhouse gas emissions of China are still high and are expected to rise, although China has taken serious steps in solving the problem. Increasing efforts to conserve energy may contribute significantly to the mitigation attempts to global warming. Therefore, it is necessary to understand how reducing the growth rate of energy consumption may affect the economic growth rate in China. This paper investigates the temporal relationship between the growth rates of energy consumption and GDP in China in a multivariate framework. We find some evidence that China may consider reducing the growth of energy consumption without significantly hampering economic growth.

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\textit{Keywords:} Energy consumption; Economic growth; China

1. Introduction

Since it has been declared that the global warming is a serious problem that needs immediate attention (United Nations Framework Convention on Climate Change (UNFCCC), 2004), the major concern of governments has been on the reducing GHG without hindering economic growth. We cannot say that governments have been successful on this issue since one of the most important causes of global warming is the emissions of greenhouse gasses (GHG) and the main source of these GHG emissions is energy consumption. Therefore, reducing energy consumption emerges

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as a direct policy that can reduce the emissions of GHG (de Nooij, van der Kurk, & van Soest, 2003). However, if the fight against global warming involves reduction in energy consumption, then the relationship between energy consumption and economic growth should be identified.

Although there have been many attempts to identify the aforementioned relationship for specific countries, there still exist conflicting results. Probably the most important information a policy maker may need in this course of fight with global warming is the causal relationship between energy consumption and economic growth. This identified relationship shapes the long run and short run policies. If, for instance, there is no direct causality running from energy consumption to income, then energy conservation policies may be applied without much concern for economic growth in the long run. If the country in concern is economically vulnerable to reduction in energy consumption, then alternative policies such as increasing energy efficiency, increasing utilization of renewable (and environmental friendly) energy resources, decreasing energy intensity, etc., may be more viable (United Nations Framework Convention on Climate Change (UNFCCC), 2004). If there is bi-directional causality a balanced mixture of alternative policies may be appropriate. Hence, understanding the temporal relationship between energy consumption and economic growth may have important implications for environmental policies as well as growth and energy policies in all countries.

This paper examines the causality relationship between growth rates of energy consumption and economic growth in China in order to assess the country’s potential in contributing to the mitigation of the adverse effects of greenhouse gas emissions. China is the second largest carbon emitter in the world (EIA, 2003). And also it is a fast growing country with a population of more than a billion, which means that in the future the country may consume more energy sources and may produce even more GHG. To reveal the long run causal relationship between energy consumption and income growth rates in China, we employ a procedure proposed by Toda and Yamamoto (1995) (TY). The TY procedure does not require the knowledge of whether the variables are cointegrated or not. Therefore, it is not subject to pre-test biases that may exist in cointegration tests. Furthermore, the procedure can be used even if the series in concern are integrated of different orders. We further examine the link between the series employing generalized impulse responses (GIR).

In the next section, we review literature on energy consumption and economic growth. Then in Section 3, we summarize the economic and energy consumption situation in China. Section 4 describes the data. In Section 5, we briefly introduce methodological issues and discuss empirical results. We first examine the time series properties of the series in concern, and then we apply TY and GIR. Section 6 provides conclusions and discusses policy implications. Our results indicate a lack of Granger causality between energy use and GDP; hence, providing some support for the neutrality of energy hypothesis in China.

2. Literature review

There have been an abundant number of studies that examine the Granger causality (Granger, 1988) between energy consumption and GDP in several developed and developing countries without achieving unanimous results. The studies go as far as to the pioneering work of Kraft and Kraft (1978). However, the early studies employed standard Granger causality tests. The traditional Granger causality tests were criticized based on the premise that OLS yields spurious results when the variables in concern are not stationary; that is, they contain unit roots.

Recently, Granger causality between energy use and income is investigated via cointegration and vector error correction methods in time series or in panel settings (see for example, Stern,
(1993; Masih & Masih, 1996, 1997, 1998). Stern and Cleveland (2003) provide an excellent review of the earlier and recent work. Other recent examples that apply similar techniques include Soytas and Sari (2003), Sari and Soytas (2004), Oh and Lee (2004), Ghali and El-Sakka (2004), Lee (2005, 2006), Wolde-Rufael (2005), Narayan and Smyth (2005). Although application of the new techniques may have increased our understanding, they still yield different results for different countries. The differences may be arising due to two reasons. First, the studies may not be including relevant variables in their analyses. Therefore, omission of important variables may be affecting the results of the causality tests. Second, the temporal relationship between energy use and income may have different dynamics across countries and may depend on country specific properties. Hence, there may not be a single optimal policy solution to the environmental problems that is applicable in all countries.

A brief review of the literature reveals the importance of using a multivariate setting since Granger causality tests may be subject to omitted variables bias, and the importance of the time series properties of the series in concern (Stern & Cleveland, 2003; Ghali & El-Sakka, 2004). Probably, the most formal approach is due to Ghali and El-Sakka (2004) who propose a neoclassical production function framework to study the long run relationship between economic growth and energy use. It appears important to account for changes in labor and capital when examining economic growth.

Since changes in labor and capital in a country may be affecting the link between economic growth and energy consumption growth, we include fixed capital investment and labor growth in our analysis. In the next section, we discuss the energy consumption and economic growth in China to have a better understanding of country specific properties and policy options.

3. Economic growth, energy, and environment in China

We choose to study China because of three reasons. First, it is one of the fastest growing economies in the world with a growth rate exceeding 9%. Second, according to the Country Analysis Briefs, China: Environmental Issues, of Energy Information Administration (EIA, 2003) it is the second largest carbon emitter that accounts for about 13.5% of world emissions. Third, although China has taken serious measures to solve its environmental problems (reduce use of coal which is a carbon intensive resource, use taxes to provide incentives to switch to environmental friendly energy resources, introduce emission trading schemes, etc.), its emission levels remain to be high (EIA, 2003).

Chinese economic growth since 1978 has been the subject of several studies in literature. Tobin (2005) and Chen and Feng (2000) seem to attribute this economic success to the liberalization the economy went through and appearance of private enterprises, education, and openness, respectively. However, their analyses do not seem to consider energy as a possible source of economic growth. According to the forecasts of Crompton and Wu (2005), the energy demand in China will grow at a slower pace than the historical rate, which seems to be in line with the slower economic growth projections in the future. However, the increase in demand for energy will continue to be significant with an expected annual growth rate of 3.8%. Zou and Chau (in press) study the link between oil consumption and economic growth in China. They report causality running from oil consumption to income in both the short and the long runs. Their results also indicate long run Granger causality running from economic growth to oil consumption. On the other hand, Shiu and Lam (2004) report unidirectional causality running from electricity consumption to GDP in China. Wang and Feng (2003) study the impact of energy consumption on the economic development and the environmental problems of the Jiangsu region.
in China. They argue that sustainable economic development of the region requires stable energy supply.

According to the China Country Analysis Brief of EIA (EIA, 2005) coal, a high carbon intensive energy resource, accounts for more than 60% of primary energy consumption of the country. Furthermore, China is the second largest demander of oil, which is also a carbon intensive energy resource, in the world (EIA, 2005). Hence, in the long run limiting energy consumption may be the most affective tool to reduce greenhouse gas emissions. Zhang (2000) argues that economic development is a top priority in China and therefore it would not be a viable policy to impose a cap on her future emissions, unless the country reaches an unspecified level of per capita income. Although according to Zhang (2000) the largest source of carbon emissions in China appears to be economic growth, it is not too clear whether maintaining high economic growth and reducing emission levels are conflicting goals for China in the long run, since energy consumption may be driving both. Furthermore, Lin (in press) criticizes the decline in energy conservation investments in China. According to him, this trend is likely to hurt the economy as well as the environment in the long run. Therefore, whether the country can contribute directly to the fight against global warming via energy conservation measures, without hindering her long run economic growth rate needs to be studied further.

To the extent of our knowledge, the economic impact of energy conservation in China is yet to be investigated. Lin (in press) argues that economic growth goals of China may be in danger if the country does not reduce the growth rate of her energy demand. However, this argument is based on recent energy shortages that caused disruption to industrial production and does not indicate the long run relation between energy use and economic growth rates. Shiu and Lam (2004) find uni-directional causality running from electricity consumption to economic growth, but how does electricity generation and use relate to growth in total energy consumption is not examined. Soytas and Sari (2003) study the relationship between energy consumption and income for G-7 and top 10 emerging economies. However, they state that they had to drop China due to lack of data with adequate length.

As a result of serious environmental policies, the country has been able to cut energy consumption per unit of output. However, in the long run China cannot avoid her responsibility in fighting global warming (Zhang, 2000), and what matters for global warming is the total amount of emissions rather than per capita emission levels. Therefore, it would be necessary to identify policies that help achieve this goal without jeopardizing the economic development of the country. Identifying such policies may prove to be difficult and the country may benefit from the technology, knowledge, and experiences of developed countries. China may be a significant contributor to the fight against global warming (Zhang, 2000); however, her potential contribution in the long run may be even more significant. To be able to assess this potential and to meet future challenges effectively, a further understanding of the long run role of energy consumption in the Chinese economy is needed.

4. Data and data properties

We employ annual data from World Development Indicators (WDI) database for the period 1971–2002 on total labor force (L), real gross fixed capital formation (K), energy use (E), and real GDP (Y). We compute the growth rates by taking the differences of logged series.

The data in WDI database do not include data for Hong Kong, China; Macao, China; or Taiwan, China. Real GDP and real gross fixed capital formation are in constant 2000 US$. 

Table 1
Unit root test results

<table>
<thead>
<tr>
<th></th>
<th>ADF</th>
<th>PP</th>
<th>KPSS</th>
<th>NP-Z_{c1}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Levels</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Intercept</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>DLE</td>
<td>−4.328639^a (0)</td>
<td>−4.321562^a</td>
<td>0.207022</td>
<td>−14.2039^a (0)</td>
</tr>
<tr>
<td>DLY</td>
<td>−2.906872^c (1)</td>
<td>−3.930959^a</td>
<td>0.282254</td>
<td>−12.0738^b (0)</td>
</tr>
<tr>
<td>DLK</td>
<td>−4.466229^a (0)</td>
<td>−4.498878^a</td>
<td>0.322614</td>
<td>−14.3926^a (0)</td>
</tr>
<tr>
<td>DLL</td>
<td>−1.397419^c (0)</td>
<td>−1.389919</td>
<td>0.694542^b</td>
<td>0.50175 (0)</td>
</tr>
<tr>
<td>Intercept and trend</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DLE</td>
<td>−4.413822^a (0)</td>
<td>−4.394959^a</td>
<td>0.046167</td>
<td>−14.7691^c (0)</td>
</tr>
<tr>
<td>DLY</td>
<td>−3.000128^b (1)</td>
<td>−3.976008^b</td>
<td>0.148223^b</td>
<td>−13.6604 (1)</td>
</tr>
<tr>
<td>DLK</td>
<td>−5.583626^a (0)</td>
<td>−5.527319^a</td>
<td>0.234147^a</td>
<td>−15.4219^a (0)</td>
</tr>
<tr>
<td>DLL</td>
<td>−2.315308^c (0)</td>
<td>−2.462904</td>
<td>0.095362</td>
<td>−6.81788 (0)</td>
</tr>
<tr>
<td>First differences</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DLY</td>
<td>−4.908245^c (1)</td>
<td>−17.9772^c</td>
<td>0.500000b</td>
<td>−15.8346^a (0)</td>
</tr>
<tr>
<td>DLL</td>
<td>−6.475032^a (0)</td>
<td>−6.413283^a</td>
<td>0.109865</td>
<td>−20.6600^b (0)</td>
</tr>
<tr>
<td>Intercept and trend</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DLY</td>
<td>−4.866394^c (1)</td>
<td>−19.62292^a</td>
<td>0.447483a</td>
<td>−16.2224^c (1)</td>
</tr>
<tr>
<td>DLL</td>
<td>−6.411084^a (0)</td>
<td>−6.351474^a</td>
<td>0.106545</td>
<td>−15.8352^c (0)</td>
</tr>
</tbody>
</table>

D and L are first difference and natural log operators, respectively. Superscripts (a, b, and c) represent significance at 1, 5, and 10%, respectively. Lag lengths are determined via SIC and are in parentheses.

Note that although capital stock data is not readily available, we assume that the growth rate of fixed capital formation approximates the growth rate of capital stock. According to the perpetual inventory method (Jacob, Sharma, & Grabowski, 1997), assuming a constant depreciation rate indicates that changes in investment may closely follow changes in capital stock. Thus, following Jin and Yu (1996) and Shan and Sun (1998), we employ gross fixed capital formation to account for “changes in capital stock”. The energy consumption variable is in kilotons of oil equivalent. Although Sinton (2001) seems to raise some doubts regarding the accuracy and reliability of Chinese energy statistics after 1990, changes in the total energy use probably accurately represent the long run energy consumption patterns in relation to economic growth in China.

We utilize four different unit root tests to check the stationarity of the series. Augmented Dickey and Fuller (1979) (ADF), Phillips and Perron (1988) (PP), Kwiatkowski, Phillips, Schmidt, and Shin (1992) (KPSS) that are frequently used in literature, but criticized due to their low power properties for small samples. We therefore apply a relatively new test Z_{c1} developed by Ng and Perron (2001) (NP) to check the robustness of the first three tests.

The unit root test results in Table 1 imply that DLK and DLE series are I(0), (D and L are first difference and natural logarithm operators, respectively). Hence, we do not test their first differences for stationarity. However, there is some evidence that DLY and considerable evidence that DLL are I(1). Therefore, the series do not appear to be integrated of the same order.

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1 See Maddala and Kim (1998) for excellent treatment of ADF, PP, KPSS; and Ng and Perron (2001) for NP unit root tests.
Table 2
Granger causality test results based on Toda–Yamamoto procedure

<table>
<thead>
<tr>
<th>Hypotheses</th>
<th>WALD Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>DLY does not Granger cause DLE</td>
<td>2.399671 (0.1214)</td>
</tr>
<tr>
<td>DLE does not Granger cause DLY</td>
<td>0.290086 (0.5902)</td>
</tr>
</tbody>
</table>

The Wald statistics are for the joint significance of first \( q \) lags of the independent variable in the corresponding VAR equations (\( p \)-values are in parentheses).

5. Causality test and generalized impulse response results

Since the series are integrated of different orders, Toda–Yamamoto procedure to test for Granger causality appears to be the most appropriate method. Note that TY procedure does not require pre-testing for cointegration, hence it is not subject to pre-test biases. Sims, Stock, and Watson (1990) show that when the variables are integrated inferences based on level VARs are not valid since the test statistics do not follow standard distributions. However, Zapata and Rambaldi (1997) show that the TY test can be applied without pre-testing for cointegration and for any arbitrary level of integration.

The TY procedure steps are as follows:

(i) Conduct unit root tests to find orders of integration of all variables. Set \( p = \) maximum order of integration.

(ii) Determine optimum lag length \( q \) of VAR via some criteria. The lag selection is crucial especially when the theory and statistical results indicate low lag lengths in VAR. Hence, it may be better to consult several different lag selection criteria.

(iii) Estimate VAR(\( q + p \)) in levels of variables.

(iv) Conduct diagnostic tests to check robustness of VAR equations.

(v) Conduct Wald test on the first \( q \) parameters of the other variable in the VAR(\( q + p \)). If significant, then reject null of non-causality. Yamada and Toda (1998) argue that Wald statistic based on augmented VAR has an acceptable empirical size.

Note that the TY results show only long run causal relation since all growth rates are in levels (and there is no error correction term in the model).

The unit root tests indicate that \( p = 1 \). When we consider the Akaike information criterion, final prediction error, and Hannan–Quinn lag selection criteria, the optimum lag length of VAR with trend is found to be 4. However, the augmented VAR with lag length 5 turns out to be unstable\(^2\). The optimum lag length for the VAR with trend is determined via the likelihood ratio test is 1. Hence, we estimate a lag augmented VAR with 2 lags\(^3\).

Satisfied with the diagnostics of VAR(2), we proceed with the Granger causality tests, whose results are summarized in Table 2.

Table 2 reports the Wald test statistics for the Granger non-causality hypotheses. Note that both statistics are insignificant, hence we fail to reject Granger non-causality between growth rates of

\(^{2}\) VARs with lag lengths selected by different criteria do not satisfy the stability condition.

\(^{3}\) Note that VAR(2) satisfies the stability condition. The diagnostic test results indicate that the equations do not seriously violate common assumptions of no serial correlation, normality, no cross terms, and parameter stability. All diagnostic test and lag selection procedure results are available upon request.
energy consumption and income in China. Neither energy nor income growth seems to improve the forecasts of each other. Hence, reducing the growth rate of energy consumption may benefit the environment without causing a decline in economic growth rate.

Note that Granger causality tests may be viewed as endogeneity tests. The result of the test indicates whether the variables are endogenous or not. However, the test results do not consider how variables in general respond to innovations in other variables. In order to assess impact of a shock in one of the variables to the other we consider the generalized impulse responses introduced by Koop, Pesaran, and Potter (1996) and Pesaran and Shin (1998). The generalized technique is not sensitive to the ordering of variables in the underlying VAR, since it does not rely on Choleski decomposition\(^4\). Since all variables in the VAR must be stationary, we include the first difference of the growth rates of GDP and labor, and the levels of other growth rates. Fig. 1 includes generalized responses of growth rate of energy consumption and volatility in growth rate of income to one standard deviation shock in the other variable\(^5\).

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\(^5\) Since our interest is in energy consumption and income growth rates, we do not include shocks in and responses of other variables in Fig. 1. All generalized impulse responses are available from the authors upon request.
The impulse response graphs show that the initial impacts of shocks in each variable on the other are only slightly significant, compared to a highly significant self shock affects. However, the affect of the shocks die off immediately after the first horizon. This suggests that although innovations in one variable may seem to be influencing the other variable in the short run, the affect does not seem to last long. Hence, the generalized impulse response results seem to support the lack of long run Granger causality between growth rates of energy consumption and economic growth.

6. Conclusions and policy implications

The results of this paper imply that energy conservation and/or energy shortages may not hamper Chinese economic growth in the long run. Therefore, China seems to have an advantage in achieving sustainable growth without putting too much pressure on the environment. Developing environmental friendly energy sources to reduce reliance on energy sources that lead to environmental degradation, reducing energy intensity, reducing carbon intensity (Zhang, 2000) all appear to be viable policies considered by the Chinese government that appear to be consistent with sustainable development targets. However, the rapidly growing economy may become constrained by energy shortages in the near future (Lin, in press) and severe environmental problems may be faced if growth rate of energy is not controlled.

As suggested by Weidou and Johansson (2004), the focus of developing new energy sources may be shifted to the environmental friendly energy sources without much concern for significant negative impact on the economy in the long run. For example, China may overcome her heavy dependence on coal (Crompton & Wu, 2005) in the long run by relying more on hydropower and natural gas. Additionally, the country may intensify its efforts in energy conservation to reduce the growth rate of energy consumption, hence reducing the adverse impact on the environment in the future. Additional policy options might be to decrease energy and emission intensities, and increase energy efficiency. To this respect the emissions trading system considered by the government may prove to be effective.

Although, there is no consensus in the environmental Kuznets curve literature, there appears to be some support for energy use and economic growth being main sources of greenhouse gas emissions. In China, the extent to which renewable energy sources may be substituted in for fossil fuels in the long run may be rather important. Although the substitution is not likely to be perfect, such a shift may ease up the pressure on the environment. It should be noted that we employ growth in aggregate energy consumption in this paper; however, the use of disaggregate energy consumption in order to assess the relative importance of various energy sources for the Chinese economy may yield different results (see for example, Zou & Chau, in press; and Shiu & Lam, 2004). The relative importance of various energy sources in the economy may provide important information to policy makers (Sari & Soytas, 2004) regarding the substitutability. Since energy use and economic growth may be independent sources of environmental degradation in China, further study of such a link between environmental degradation, energy use, and economic growth may also be insightful.

References


