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Research Note

Coal, oil, or clean energy: Which contributes most to the low energy efficiency in China?

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ABSTRACT

The lack of energy efficiency in China is always of interest. This paper builds a total-factor energy efficiency framework which contains coal energy, oil energy, and clean energy, which emits fewer pollutants into the atmosphere when used. We study the "China Statistical Yearbook" and the "China Energy Statistical Yearbook" to identify which type of energy contributes most to low energy efficiency in China. Our conclusion is that the total-factor energy efficiency (*TFEE*) in China has been at a relatively low level without any significant improvement from 1998 to 2010. The efficiencies of coal and oil energy have improved moderately, while there is no obvious improvement in the efficiency of clean energy. Despite the moderately improved efficiency of coal energy, its relatively low level contributes most to the overall energy inefficiency because it is the main fuel used in China. Further, the lack of improvements in the efficiency of clean energy makes it another area of policy interest.

1. Introduction

Global warming is a hot topic in environmental policy. The effects of an increase in global temperature include a change in the amount and pattern of precipitation, more frequent extreme weather events, as well as the threat to food security from decreasing crop yields and the loss of habitat from inundation. Greenhouse gases, which trap heat in the atmosphere, are blamed for making the planet warmer. Therefore, reducing the emissions of greenhouse gases in energy production becomes one of the main tasks for economic development worldwide. As the second largest economy and the largest energy consuming entity,[1] in 2005, China has promised to reduce the energy intensity,[2] which is a measure of the energy inefficiency of a nation's economy, by 40%–45% of 2020. This objective was established before the 2009 climate change conference in Copenhagen, and it has posed a challenge to Chinese economic development.

According to the Guide to China's Energy Statistics, clean energy mainly depends on hydropower and natural gas, can be used in many ways help reduce the emissions of pollutants into the atmosphere. Delving into the current structure of energy consumption in China, we find that coal energy, oil energy, natural gas energy, and clean energy accounted for 68%, 19%, 4.4%, and 8.6% of the total energy consumption, respectively, in 2010. It reveals that high-polluting coal is still the major source of energy in China. According to the provincial structure of the energy intensity survey, the top five energy efficient provinces account for 14.13% of total energy consumption and contribute to 24.53% of GDP. However, the top five energy inefficient provinces account for 15.84% of total energy consumption but contribute to only 7.17% of GDP. The comparison shows that the energy configuration lies at a point which is remote to the optimal frontier of energy efficiency in China. Therefore, not only would the improvement of energy efficiency as a whole help lower energy consumption, but also reshaping the allocating structure of energy would be another solution to achieve low-carbon economic development.

The paper proceeds as follows. Section 2 summarizes prior literature. Section 3 elaborates on the framework for total-factor energy efficiency. Section 4 shows the data set and the summary statistics. Section 5 exhibits the main results. Section 6 concludes.

2. Literature review

Energy efficiency in China has been studied by numerous research projects. Inspired by the method used in Data

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[1] From < The BP Statistical Review of World Energy 2012>.
[2] Energy intensity = Gross Domestic Product/Energy Consumption.

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Envelopment Analysis (DEA), Hu and Wang (2006) investigated Chinese provincial data from 1995 to 2002 and found that the middle areas of China were the least energy efficient districts. But the energy efficiency there could be improved by economic development. Using the dataset of 17 APEC countries from 1991 to 2000, Hu and Kao (2007) found that China had the lowest energy efficiency among the APEC countries. Relying on the concept of TFEE and the Luenberger productivity index, Chang and Hu (2010) built up the index of total-factor energy productivity (TFEPI) to quantify the changes of TFEE, and concluded that the TFEPI decreased by 1.4% each year from 2000 to 2004. Zhang et al. (2011) also studied the energy efficiency of developing countries via the index of TFEE and argued that China's energy efficiency experienced the largest growth from 1980 to 2005. Wang et al. (2012) found that the Chinese industrial sector had the potential to reduce energy consumption. The two reasons for energy inefficiency were insufficient technological investment and diseconomies of scale. From the above analysis, we conclude that the average level of Chinese Provincial TFEE is a relatively low. What's more, there exists a significant disparity between provinces. However, the research above considers energy generated from burning coal and oil without respect to other sources of energy.

Our paper contributes to prior literature through the following two aspects. First, the energy resources include not only coal and oil, but also natural gases and electricity (i.e., Clean Energy) in China. Then we apply a non-radical input distance function to establish the framework of total-factor energy efficiency. Second, the paper investigates coal energy efficiency, oil energy efficiency, and clean energy efficiency under the framework of total-factor energy efficiency.

3. Conceptual framework

First, we investigate two main indices that have been applied to describe the energy efficiency. The first index is energy intensity which calculates the ratio of regional GDP over energy consumption to measure energy efficiency. However, energy intensity is vulnerable to noise such as changes in industry structure (Wilson et al., 1994) and changes in energy price levels (Boyd and Pang, 2000). Therefore, the index of energy intensity is not robust to the various situations in terms of energy usage (Patterson, 1996).

To circumvent the disadvantages in energy intensity, Hu and Wang (2006) proposed another index of total-factor energy efficiency (*TFEE*) which uses the ratio of the optimal energy inputs to the real energy inputs to measure energy efficiency. The advantage of this index is that it can accommodate non-energy inputs, such as labor and capital, to measure energy efficiency. Similar to the approach brought about by Hu and Wang (2006), the paper constructs the framework as follows.

Thirty provinces[3] in China are the provincial-level decision making units. Then we build up the production frontier, in which the energy inputs of energy are coal (C), oil (O), and clean energy (Q); and the non-energy inputs are capital (K) and labor (L). Gross Domestic Product (G) is the output measure.

$$T = \left\{ (K_{it}, L_{it}, C_{it}, O_{it}, Q_{it}, G_{it}) \in R^I \right\}, \quad i = 1, 2, \cdots, 30 \tag{1}$$

T is production technology which links the inputs, (K, L, C, O and Q) to the output, (G). i is the provincial index.

Using the Shephard input distance function (Shephard, 1970), we set the framework of TFEE to be:

$$T = \left\{ \begin{array}{l} \max w_1\alpha_{it} + w_2\beta_{it} + w_3\gamma_{it}, \\ (K_{it}, L_{it}, C_{it} - \alpha_{it}C_{it}, O_{it} - \beta_{it}O_{it}, Q_{it} - \gamma_{it}Q_{it}, G_{it}) \in R^I \\ w_1 + w_2 + w_3 = 1 \\ \quad i = 1, 2, \cdots, 30 \end{array} \right\} \tag{2}$$

w_1, w_2 and w_3 denote the source weights, which are measured by the proportion of the total energy generated from coal, oil, and clean resources. $w_1\alpha$, $w_2\beta$, and $w_3\gamma$ are the ratios of the resource reduction with respect to coal energy, oil energy, and clean energy, respectively. The index of TFEE can be written as follows.

$$\begin{aligned} TFEE &= \frac{w_1(C_{it} - \alpha_{it}C_{it}) + w_2(O_{it} - \beta_{it}O_{it}) + w_3(Q_{it} - \gamma_{it}Q_{it})}{C_{it} + O_{it} + Q_{it}} \\ &= w_1(1 - \alpha_{it}) + w_2(1 - \beta_{it}) + w_3(1 - \gamma_{it}) \end{aligned} \tag{3}$$

In equation (3), *TFEE* consists of three parts: $w_1(1\text{-}\alpha)$ is the contribution of coal energy to TFEE, and $w_2(1\text{-}\beta)$ is the contribution of oil energy to TFEE, and $w_3(1\text{-}\gamma)$ is the contribution of clean energy to TFEE.

In contrast, the total-factor energy inefficiency (*TFEI*), which calculates the ratio of the potential of resource savings to the actual energy consumption, is:

$$\begin{aligned} TFEI &= \frac{w_1\alpha_{it}C_{it} + w_2\beta_{it}O_{it} + w_3\gamma_{it}Q_{it}}{C_{it} + O_{it} + Q_{it}} \\ &= w_1\alpha_{it} + w_2\beta_{it} + w_3\gamma_{it} \\ &= 1 - TFEE \end{aligned} \tag{4}$$

4. Data and descriptive statistics

4.1. Data

The primary data sets we analyze are the “China Statistical Yearbook” and the “China Energy Statistical Yearbook”. Coal consumption (C), oil consumption (O), clean resources consumption (Q), capital stock (K), and labor force (L) are coded as the five input variables. The Gross Domestic Product (GDP) is used to measure output. Given the missing values of provincial-level variables, our sample is restricted to thirty Chinese provinces without missing values and the time periods from 1998 to 2010. Capital stock values calculated by Zhang et al. (2004); and the values for other variables are retrieved from the “China Statistical Yearbook” and the “China Energy Statistical Yearbook” from 1998 to 2010. Capital stock and real GDP are deflated by the price levels in 1998, which is the base year.

Table 1 yields the descriptive statistics of the input and output variables.

Table 1
Description and summary statistics of variables.

	Unit	Average	Max	Min	Std. Dev	C.V
L	10,000 person	2365.59	6401.90	254.84	1581.27	0.67
K	100 million RMB	6415.78	34518.67	348.27	5893.44	0.92
C	Ton of standard coal	4883.45	22712.65	88.31	4032.88	0.83
O	Ton of standard coal	1428.31	7650.99	5.14	1396.75	0.98
Q	Ton of standard coal	1191.54	5806.71	60.22	982.73	0.82
G	100 million RMB	1191.63	3368.01	114.81	743.77	0.62

[3] Due to the availability of data, the sample doesn't include Hong Kong, Macao, Taiwan and Tibet.