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How to reduce energy intensity in China: A regional comparison perspective

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HIGHLIGHTS

- We examine the factors influencing energy intensity across different Chinese regions.
- Energy intensity is influenced by different factors among three regions. Technological progress is further decomposed into three elements.
- Technological change has a negative effect on energy intensity in the Central region.

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ABSTRACT

China faces growing environmental problems as rapid economic growth comes at the cost of excessive resource consumption. Sustainable development can only be realized by reducing energy intensity. Although some general factors that influence energy intensity have been described, less information is available to compare energy intensity in different regions. Here we use existing literature to assess the effects of three internal factors (economic structure, energy consumption structure, and technological progress) on energy intensity in three regions of China. We use panel data from 2000 to 2009 and find that the effects of each factor differ in each region. We further differentiate these effects by decomposing technological progress into three parts using the DEA-Malmquist approach. We find three components of technological change have completely different effects in each region. Furthermore, these findings are applied to propose relevant suggestions to reduce energy intensity in different regions of China.

1. Introduction

Since the economic reforms of 1978, China has experienced dramatic economic growth; the gross domestic product (GDP) grew from 364.5 billion RMB in 1978 to 34,346.5 billion RMB in 2009 (NBS-a). This remarkable economic growth has resulted in extremely high energy consumption, which increased from 0.57 billion tons of coal equivalent (TCE) in 1978 to 3.06 billion TCE in 2009 (NBS-b), triggering a series of environmental and resource sustainability problems.

In recent years, academics and practitioners have paid increased attention to environmental issues caused by high-energy consumption. Among these issues, energy intensity (the ratio of total energy consumption to GDP) has long been of interest to energy researchers (Asami, 2001). As a measure of energy efficiency, energy intensity indicates human development and progress, economic structure, fuel mix, and the technological level of a country (Sun, 2002). In addition, policies that decrease energy intensity are an important means to reduce energy-related carbon dioxide emissions and save non-renewable resources, such as coal, fossil oil and natural gas. Therefore, governments aim to develop national energy policies that reduce energy intensity (Farla and Blok, 2000).

Research on energy intensity in China is especially important for three reasons. First, although energy efficiency is low, sustained high economic growth has increased energy consumption. China became the second-largest economy after the United States in 2011(BP, 2007 and 2008), and it cannot neglect Chinese economic development takes effects on the global economy. Increased energy consumption is a cost of rapid economic development, and consumption will continue to rise for many years (Ma et al., 2009), However, The problem of energy efficiency in China

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not only influences global economic trend, but also causes the market of energy shocks and fluctuations. In 2004, China consumed 8%, 10%, and 31% of the global output of crude oil, electricity, and coal, respectively, but only produced 4% of the global GDP. This problem is exacerbated by environmental consequences of energy inefficiency (Hang and Tu, 2007).

Second, a developing country's energy intensity increases with increased industrialization, urbanization, and infrastructure construction (Sun, 2003). China is the largest developing country in the world and its energy intensity is unlike other developing countries. The trend of energy intensity in China gradually decreases year by year.

Third, as global non-renewable energy resources are depleted, China will need higher efficiency and lower energy consumption to maintain economic growth. In addition, environmental damage also compels China to do everything possible to improve energy efficiency. An analysis of Chinese energy consumption and corresponding characteristics is necessary.

Energy issues are also influenced by variations in economic growth, natural environment, and technological development in different parts of China. Here, we explore the factors influencing regional differences by dividing China into Eastern, Central, and Western regions[1] according to natural and social resource endowments, historical development, and level of economic development (Fan and Zhang, 2004; Wen, 2009).

Many researchers have investigated the determinants of China's energy intensity. Wei et al. (2006) used data from 1997 to analyze the impacts of economic and social change on energy intensity in 2020. Their results implied that technological progress had the strongest impact on energy intensity. Recently, Zheng et al. (2011) concluded that several internal factors related to the Chinese economy affected energy intensity. These authors suggested that technological progress, structural changes, and changes in energy consumption have decreased energy intensity over the past two decades. Embodied in a free trade, technology transformation and talents moving, technological progress has been regarded as principal factors by most previous literatures.

Although many authors agree technological change is the dominant factor influencing energy intensity, the influence of structural change should not be overlooked (Ma and Stern, 2008; Ma et al., 2009; Sue Wing and Eckaus, 2004). Dowlatabadi and Oravetz (2006) argued that structural shifts and technological progress changed energy intensity. In addition, technological progress is identified as a key driver of change in economic structure and energy efficiency. Liao et al. (2007) suggested that China should optimize its sectional structure to improve energy efficiency. Most of the declines in energy intensity are accounted by the effect of technological progress, while the structural effect is negative and slight. Zhao et al. (2010) found that change in industrial structure also increased energy intensity. Consequently, governments can employ advanced technologies and adjust the economic structure to reduce energy intensity. Zhang (2003) also highlighted the importance of structural change and pointed out that the decline in energy intensity in the 1990s stemmed from structural changes. Shifts in China's economic structure have also emerged as the principal force of China's declining energy intensity and consumption (Fisher-Vanden et al., 2004).

[1] The Eastern region includes Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, and Hainan; the Central region includes Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, Hunan; the Western region includes Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang, Guangxi, Inner Mongolia, Tibet (no available data). Coastal region mainly refers to the Eastern region, and inland region contains the Central region and the Western region.

The structure of energy consumption also significantly influences energy intensity. Coal provides about 70% of the primary energy consumption, and since 1986 China has been the world's largest coal consumer (BP, 2009). China's long-term energy policy and planning assumes that coal will provide most of the energy required for the next 20 or 30 years (Yang, 2008). Energy intensity will decrease significantly if more renewable energy can be used. Wu (2008) believed that the development of renewable energy could decrease energy intensity by bringing in new energy technology. Renewable energy development helps reduce energy intensity by innovative use of technology (Gao et al., 2005; Martinot, 2001a, 2001b). Fisher-Vanden et al. (2004) implied that China's energy intensity has declined because coal consumption has decreased. Feng et al. (2009) also found that energy consumption structure had a positive effect on energy intensity in the short-run.

Zheng et al. (2011) identified three internal factors (technological progress, economic structure and energy consumption structure) related to the Chinese economy that influence energy intensity (Zheng et al., 2011). However, most of the previous studies on China's energy intensity have been done from an overall perspective that ignored the differences among regions.

In addition, although technological change has been discussed as a whole, we cannot identify the degree to which components of technological change influence energy intensity. This suggests we should deeply analyze technological change. Although the object and content differ, these studies may provide more information than can be derived from research of the individual components of technological change (Chen and Iqbal Ali, 2004). Further decomposition of technological change is important to facilitate a multilateral comparison of the differences and similarities in growth patterns in different regions (Chang and Luh, 2000). We are unaware of any detailed current research into the constituents of technological change and energy. Related energy papers focus excessively on the effects of technological change, but overlook the significance of components of technological change.

Here we first model these three internal factors to compare the impact of each factor on energy intensity in different regions of China, and then discuss the effects of technological progress by decomposing technological progress into pure efficiency change, Technical change and scale efficiency change using the DEA-Malmquist method proposed by Färe et al. (1994). Our aim is to answer two questions: (1) Do these internal factors have different effects on energy intensity in the three regions? (2) Which component of technological progress more effectively decreases energy intensity in each region?

Section 2 of this paper introduces the research method. Section 3 describes the variables, data collection, and data analysis. Section 4 discusses the results and section 5 presents a conclusion, policy implications and directions for future study.

2. Method

2.1. DEA-Malmquist method

Caves et al. (1982) and Färe et al. (1994) proposed a Malmquist index based on output. The Malmquist total factor productivity (TFP) index is defined as the ratio of efficiency measures for the same production unit in two different time periods, or between two separate observations in the same period (James, 2000). The Malmquist index expressed as a Data Envelopment Analysis (DEA) measures TFP change over time, and has proved well suited for measuring productivity change (Chen and Iqbal Ali, 2004). In this research, we employ TFP to measure technological progress. The Malmquist (input-oriented) TFP change index between period