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Impact of factor price distortions on energy efficiency: Evidence from provincial-level panel data in China

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ABSTRACT

The marketization of energy price is not only an important part of factor pricing reforms but also decisive for energy efficiency improvement. Thus, this study aims to measure factor price distortions and estimate their impact on energy efficiency based on an empirical analysis of 30 provinces of China during 2004–2013 using the stochastic frontier analysis framework. Results yielded three important findings: (1) Technical efficiency was the highest in eastern China, which still remains low at around 0.7980, followed by central China and western China, and there were growing gaps among the above areas. (2) Capital price was relatively high while energy price was relatively low compared with labor price, and the relative allocative efficiency of energy got worse over time. (3) Energy efficiency loss among the three regions showed convergence trends. Policy implications are summarized as follows: (1) Measures such as adjusting energy consumption structure and improving production technology and management levels can reverse the trend of declining technical efficiency. (2) The process of energy price marketization needs to be accelerated. (3) It is necessary to expand the depth and breadth of regional technology diffusion and break the barriers of technology transfer among regions in China.

1. Introduction

Pricing reform in China has transitioned from a dual track system to a market-oriented system since 1978. However, the market-oriented reform was asymmetric. The commodity market has experienced fundamental transformations after China's entry into the World Trade Organization, and has reached a high degree of marketization due to sustained reform (Ouyang and Sun, 2015). However, the marketization process of the factor market was still relatively slow, and much of the factor markets remained heavily distorted (Huang, 2010; Yang et al., 2018; Young, 2000; Zhang and Tan, 2007). These distortions generally depressed prices of production factors including those of labor, capital, land, energy and other resources, and the environment, which resulted in structural imbalance problems in China. As the “visible hand” (responsible government agencies) continues to play a leading role in the pricing of production factors, energy price has been depressed in China over the past decades (Sun and Lin, 2013). When the energy price is less than the marginal energy output, it can easily lead to excessive use of energy, thereby reducing energy efficiency (lower output with the same input of energy).

China surpassed the United States to become the world's largest energy consumer in 2010, and its energy consumption was expected to continue growing due to the urbanization process. In this context, as energy resources are not abundant in China, growing energy consumption would lead to high dependence on energy imports (Dai and Cheng, 2016). To solve the above problems, the Chinese government vigorously promoted the elimination of backward production facilities during the “11th Five-Year Plan” period (2010–2015). In October 2015, the “Opinions of the China Central Committee and the State Council on Promoting the Reform of the Price Mechanism” was issued, which clearly stated the need to accelerate the marketization of energy price and restore the commodity attributes of energy; it also put forward the target that an energy price system determined by the market would be established by 2020, with the price mechanism spontaneously adjusting the supply and demand of energy. Therefore, improving energy efficiency and reducing energy consumption have become important issues in academic research and for policymaking.

Significant regional difference exists in the aspect of factor price distortions in China. There was persistence in labor misallocation in China (Bai and Cheng, 2015), and labor market distortions have regional disparities (Cai et al., 2002). China's household registration system (HRS), known as the *Hukou* policy, was instituted in the 1950s.

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It designated the permanent legal place of residency and work for Chinese citizens, which resulted in severe misallocation of labor between rural and urban sectors. Although the *Hukou* policy has been reformed since 1978 to promote rural labor mobility, it still has strict restrictions on obtaining urban residence permits in mega cities in China such as Beijing, Shanghai, Guangzhou, and Shenzhen. For instance, people of non-local households in the abovementioned mega cities are not entitled to normal urban social welfare benefits. Research shows that migrant workers' wages are still lower than those of urban residents. This restricts the population flow among different areas and holds back the reasonable configuration of labor resources within the scope of whole country (Vendryes, 2011). As for capital, the local government can benefit from a financial system that prioritizes capital allocation to state-owned enterprises (SOEs) (Walter and Howie, 2011). Besides, some policies, such as the Western Development Strategy, tend to make capital allocation deviate from market regulation. All of the above factors lead to regional differences in capital price distortions. In terms of energy, most of the four largest energy industries of oil, electricity, coal, and natural gas are monopolized by large SOEs, which have the authority to set a unified price of energy. The government tends to depress energy price through administrative power to ensure high energy prices do not disrupt production and consumption, and to support rapid economic growth.

Scholars have paid close attention to the impacts of factor price distortion on energy efficiency. Most existing studies measured the effects based on the industry level (Ouyang and Sun, 2015; Tao et al., 2009) and enterprise level (Boyd, 2008; Hu, 2014). Despite the recognized importance of regional disparity in measuring energy efficiency in China, the measurement and comparison of regional factor price distortions and their effects on allocative efficiency are still relatively rare. Considering the imbalanced economic development and uneven diffusion of production technologies among regions in China, this study sheds light on the important issue of the effects of factor price distortions on regional energy efficiency based on an empirical analysis of 30 provinces of China. It can help us to better understand the sources of the rising gaps of technical efficiency among different regions in China, and to illuminate the nature of future challenges in promoting balanced regional development. The goal of this study is to address some of these questions, discuss energy efficiency loss among regions in China, and present evidence in favor of designing a more effective energy pricing reform. Chinese provinces have significant disparity in terms of factor endowments, developmental level, and industrial structure; therefore, energy efficiency has practical significance to reasonably analyze China's regional price distortion and allocative efficiency.

Areas for future research are also identified. For example, although this article comprehensively analyzed the regional disparity in terms of technical efficiency, allocative efficiency, and energy efficiency, the systematic impact of factor price distortion on energy efficiency still needs further study. In addition, it is problematic to assume an aggregate production function that ignores the industry structure differences to estimate provincial-level technical efficiency. Therefore, identifying ways to more accurately measure provincial-level energy efficiency with an improved measurement method that considers heterogeneity among regions in China is the most important direction for future research.

2. Literature review

2.1. Energy efficiency measurement

Two treatments are commonly used to measure energy efficiency: data envelopment analysis (DEA) and stochastic frontier analysis (SFA). DEA is a non-parametric estimation method, which is usually used to measure the change in technical efficiency when input factors change in the same proportion (Battese and Coelli, 1992). As a result, the efficiency of all inputs, including energy efficiency, is measured in terms of technical efficiency (Hu, 2014), which is easily influenced by extreme values (Lin and Long, 2015). Mardani et al. (2017) reviewed and summarized the different models of DEA that have been applied by 144 published scholarly papers to measurement of energy efficiency.

The SFA is a method of parameter estimation, which needs to assume the estimation function in the form of a stochastic frontier. The SFA can separate the influence of random factors when the efficiency frontier is determined; therefore, it is hard for it to be affected by individual inaccurate data points. Based on the above characteristics, SFA is widely used for measuring energy efficiency and decomposing the causes of energy efficiency losses. For instance, considering the presence of allocative inefficiency, Hu (2014) measured plant level energy efficiency in China's energy sector based on 150 coal mines, power plants, and petroleum refineries. By using the stochastic frontier production function model, Ouyang and Sun (2015) studied energy allocative efficiency in China's industrial sector. By using the Shephard energy distance function and adopting the SFA, Zhou et al. (2012) indicated that the proposed parametric frontier approach has higher discriminating power in energy efficiency measurement compared to its nonparametric frontier counterparts. Table 1 lists the representative literature focusing on the energy efficiency measurement.

2.2. Measurement of factor price distortion

Scholars have done extensive empirical work on the treatments of measuring the price distortion of production factors. Since factor price data are difficult to obtain, many studies adopted the market index as a proxy for the factor marketization degree. For instance, Lin and Du (2015) used the product marketization index in provincial regions, factor marketization index, and the overall marketization index to establish the index of factor market distortion. Through artificial transformation, these indexes adopted by previous studies pose the risk of distortion. Many other studies used the shadow price model (Khademvatani and Gordon, 2013), of which the basic idea is to measure the ratio of factor price under optimal conditions (i.e., minimizing the cost or maximizing the output) and compare the value of the ratio with 1. Tao et al. (2009) studied the industrial sector's energy price distortions and factor substitutions through the shadow price model, finding that the labor price distortion was the most serious, followed by energy price. Ouyang and Sun (2015) used the shadow price model to measure the degree of factor price distortion as well as allocative inefficiency in the Chinese industry sector, reaching a similar conclusion that capital price was relatively high, while labor price was relatively low compared with energy price.

The basic ideas of other research methods are similar to that of the shadow price model. Kumbhakar and Wang (2006) used the alternative primal system consisting of the production function (trans-log) and first-order conditions of cost minimization to estimate observation-specific technical and allocative inefficiency. Wang and Shi (2015) established a time-varying elasticity production function model to measure the degree of China's overall factor price distortion from 1978 to 2011. Hu (2014) measured factor price distortion through the ratio of marginal output to factor price. This method calculates energy efficiency through a comparison between the optimal investment and actual investment. Although it is not commonly used, this method follows the original idea of productive efficiency.

3. Methodology and data sources

3.1. Methodology

3.1.1. Theoretical framework

Productive efficiency is defined as the degree of success achieved by producers in allocating their disposable income and production in order to achieve a certain production target (Kumbhakar and Lovell, 2003).