Resources Policy 47 (2016) 178–186

Contents lists available at ScienceDirect

Resources Policy

journal homepage: www.elsevier.com/locate/resourpol

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Safety and environmental inputs investment effect analysis: Empirical study of selected coal mining firms in china

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ARTICLE INFO

Article history:
Received 8 October 2015
Received in revised form
29 January 2016
Accepted 1 February 2016

Keywords:
Coal industry
Efficiency
Safety investment
Cleaner production investment
China

ABSTRACT

This study uses 2007–2012 panel data of 51 out of 100 top Chinese coal mining firms to calculate total factor productivity (TFP) and technical efficiency (EF) using Malmquist index. The study further examines the effects of safety, cleaner production investment and technological progress (represented by research and development (R&D) input variable(s)) on industry's efficiency using Stochastic Frontier Analysis method (SFA). Results show that: (1) during the sample period, the average TFP of coal industry was relatively steady while the EF deteriorated; (2) larger coal firms have higher TFP and EF than smaller ones; (3) Technological progress has positive significant affects on EF, while safety and cleaner production inputs and the intersection of both factors separately exerts negative impacts on EF. Conclusions and recommendations are then made that: (1) if the main focus of coal industry's policy and regulation is on embracing short-term improvements and adopting market mechanisms, then safety and cleaner production investment will be left out (2) focus should be on encouraging long- term increases in safety and cleaner production investments, while providing coal firms with step by step guidance on this investment; in order to avoid negative effects abrupt increases my exert on industry's EF and enable production through realistic economic means. (3) Short term focus should be on leading larger coal firms to increase technological changes so as to improve EF in the short run. (4) Moderation of the largest firms operations should be considered in order to maximize EF through technological progress.

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1. Introduction

Coal is the main energy source and an important industrial raw material in China. For this reason, China's coal industry is basic and important to the country's energy security and economic growth. Moreover, the current accelerated industrialization in China has largely been dependent on domestic coal resources; therefore, coal industry plays an irreplaceable role in energy supply. However, evidence and observations points to the fact that extensive expansion of China's coal industry has been characterized by frequent occurrence of mine accidents, high fatality rates, serious wastage of resources, extensive environmental impacts, low technological levels and low efficiencies (Si et al., 2010; Xueqiu and Li, 2012; Chen et al. 2013; Gao, 2014). To solve these problems, in 2007 the National Development and Reform Commission enforced the "coal industry policy" that aims to regulate, with a view of promoting healthy and development of coal industry. This includes recognizing and encouraging investments in safety inputs (e.g. safety technology, education, etc) and environmental inputs (e.g. cleaner production, coal washing, waste reduction and recycling etc.) into the coa5l industry. Nevertheless, since 2013 to present the country is still experiencing occurrence of severe fog and haze, as well as other safety and environmental impacts attributed to the coal industry. Hence Government implemented and imposed more regulations on this industry as evidenced by the promulgation of the State Council Plan of Action for the prevention of air pollution and opinions on promoting smooth operation of the industry. Moreover, National Energy Board also initiated "the coal industry policy" (revised draft) and was put up for public comments. However, since coal industry shoulders the national energy security, reasonable and sound regulations and policies that enhance industry's level of efficiency should be the main goal of the industry's policy. Only through these, many problems within the industry can be solved and hence resulting to development of the industry.

Safety and environmental inputs investment being part of best practices for promoting healthy development of coal industry, they are considered "optional inputs" by many firms in a competitive production process. The "marketable output" (Product or revenue)

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http://dx.doi.org/10.1016/j.resourpol.2016.02.002
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is however considered "desirable output" while safety and environmental outputs (whether in better or worse) are considered "undesirable outputs" and hence, its respective investment is considered additional cost(s) aimed at reducing profits. Nevertheless, much as significant investment in safety and environmental inputs may seem to put firms at an economic disadvantage and hence, being a reason enough to be ignored in production process, Si et al. (2010) reports that deterioration of the environment can be costly to the production process itself. Likewise, compromised safe working environment may lead to increased accidents and/deaths; hence, more loses can be realized due to workers' compensation payment and production disruptions (Moore et al., 2010; Yakovlev and Sobel, 2010; Asfaw et al., 2013). In view of this, safety and environmental inputs investment is critical in the production process despite being associated with trade off of directly reducing profits. Moreover, much as the fact of the "trade-offs" stands, Chinese government seeks to re-regulate coal industry through implementation of evidence based measures (including significant investment in safety and environmental inputs)from scientific investigation of China's coal industry efficiency levels. Furthermore, it seeks to evaluate the impact of existing major regulation and policy effects on efficiency of coal industry, its necessity and practical significance. This study therefore, analyses the perspectives of input and output productivity and technical efficiency of China's coal industry; with focus on assessing work safety, cleaner production and technological progress levels knock-on effects on China industry's technical efficiency. The relevant corresponding policy implications and recommendations are also provided by this study.

2. Literature review

2.1. Efficiency of the firm and its respective measurements

A company requires the use of capital, labor, raw materials and other production factors to generate products. Therefore, efficiency from the perspective of input and output can be understood from two aspects namely; productivity and technical efficiency. Thus, firm's productivity is measured by the output per unit of input, while technical efficiency is measured by the ability of enterprises to make effective use of existing production factors. Nevertheless, in order to evaluate the effectiveness of these definitions, the concept of "optimal" is often used in economics. The best definition of an economic system with optimal production is represented by a condition where maximum output is achieved with minimum costs; also referred to as cost of production frontier or frontier. With "optimal" point as a reference, the producer behavior in terms of efficiency, the root causes of inefficient production and the extent of invalidity of "optimal" production can be understood; and hence, appropriate measures to improve efficiency can be proposed.

At methodological level, Debreu (1951) first proposed standard method for measuring efficiency; and is defined as the ratio of optimal investment and actual investment, or the ratio of actual output and optimal output. On this basis, Farrell (1957) defined efficiency of enterprises under the input conditions. In practice, production frontier is determined in two ways: Using parametric methods where econometric models on frontier production function and statistical estimates are employed as well as using non parametric methods by solving mathematical programming. In terms of parametric methods, emphasis is based on the two most commonly used approaches called Stochastic Frontier Analysis (SFA) and Deterministic Frontier Analysis (DFA) (Acquah, 2014; Biswas and Verma, 2013). On the other hand, the most emphasized non-parametric methods include Data Envelopment Analysis (DEA) and Free Disposal Hull (FDH) (Acquah, 2014; Daraio and Simar, 2007).

Deterministic Frontier Analysis as parametric frontier method was constructed based on statistical techniques; however, this technique assumes that all deviation from the frontier is as a result of inefficiency and none are from either measurement error or noise (Biswas and Verma, 2013). On the other hand, Stochastic Frontier approach recognizes that the deviation from the efficient frontier may be due to inefficiency and noise. Thus, SFA addresses some of the limitations associated with deterministic frontier by introducing a disturbance term to represent measurement error, noise or exogenous shocks of which cannot be controlled in the production unit (Biswas and Verma, 2013). For Data Envelopment Analysis (DEA) and the Free Disposal Hull (FDH) as nonparametric approaches, are both deterministic in nature as they make no assumption on measurement error, noise or exogenous shocks on deviation from efficient frontier, but rather inefficiency (Daraio and Simar, 2007). DEA is based on linear programming in measuring firm's efficiency and/or performance (Acquah, 2014). On the other hand FDH estimator can be said to be the "more general version of DEA estimator" due to its reliance on "free disposability" assumption to construct production possibility set (Ibid). This method was proposed by Deprins, Simar and Tulkens in 1984 and recently, some authors have raised doubts about its economic meaning (Daraio and Simar, 2007).

Nevertheless out of these, DEA method is the most preferred and is widely used by most Researchers in coal industry efficiency studies as compared to FDH, SFA and DFA; mostly because it is easy to apply as it does not assume the functional form (Chen, 2007). Moreover, as non-parametric technique, it enables making estimations and comparisons in the presence of multiple inputs and outputs. Conversely, much as this technique has this advantage; the main drawback (together with DFA and FDH), lies in that it is influenced by lack of assumption of measurement error or noise in firm's inefficiency determination; hence, resulting into "super-efficient" outliers (Daraio and Simar, 2007). Therefore, in order to eliminate outliers and extreme points in efficiency analysis and determination, stochastic frontier analysis is recommended. Hence its use in this study is reasonable. Thus, SFA allows decomposition of the deviations from efficiency frontier, to determine whether is from noise or pure efficiency (Barros, 2004; Chen, 2007). Moreover, the advantage of SFA lies in the fact that it utilizes statistics to investigate and validate model specifications and hence, ensuring accuracies in estimation (Chen, 2007). In this study, SFA method is preferred and used because of its strengths in estimating efficiency.

As a basis for this article, there are a number of studies that researchers have carried out using firm-level or provincial-level data to evaluate efficiency of China's coal industry. For instance, Jingwen et al. (1999) used DEA method to analyze technical efficiency and scale efficiency of China coal enterprises using 1994–1997 data of 64 Chinese coal enterprises. In this study, 64 coal enterprises were divided into 5 categories and among these, only 10 were reported to be technically efficient. Furthermore, Ding (2009) conducted a study on 16 listed companies to measure technical efficiency of China's coal mining industry using Malmquist index. Findings indicated that coal companies had gradually improved in their technical efficiency trend; however, the overall level of efficiency was still low, and attributed this to the prevalence of more serious investment congestion problems. Moreover, Zhang and Zhao (2011) used 2001–2008 coal industry data of China's 27 provinces and cities. Results suggested that the overall technical efficiency of domestic coal industry was low, but a better trend was observed such that in 2008, the national coal industry's TFP average growth rate of 0.6% was reported. This growth was reported to come from technical efficiency and a smaller

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