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Examining the cost efficiency of Chinese hydroelectric companies using a finite mixture model

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ABSTRACT

This paper evaluates the operational activities of Chinese hydroelectric power companies over the period 2000–2010 using a finite mixture model that controls for unobserved heterogeneity. In so doing, a stochastic frontier latent class model, which allows for the existence of different technologies, is adopted to estimate cost frontiers. This procedure not only enables us to identify different groups among the hydro-power companies analysed, but also permits the analysis of their cost efficiency. The main result is that three groups are identified in the sample, each equipped with different technologies, suggesting that distinct business strategies need to be adapted to the characteristics of China's hydro-power companies. Some managerial implications are developed.

1. Introduction

This article examines the technical efficiency of a sample of Chinese hydro-power plants from 2000 to 2010 with the finite mixture stochastic frontier model (Orea and Kumbhakar, 2004). The analysis of energy efficiency can yield significant insights into the performance of energy units and their potential for increasing productivity and improving resource use (See and Coelli, 2012).

The main issue in efficiency analysis is the benchmark choice by which the hydro-power companies are analysed. In papers with a national focus, the hydro-power plants' benchmarks are other plants in the same country (Boyd, 2008; Farsi and Filippini, 2004; Managi et al., 2006; Vaninsky, 2006). The present paper innovates in this context, first, by analysing quantitatively for the first time the efficiency of a sample of Chinese hydro-power companies and second, by controlling for unobserved heterogeneity (Greene, 2005; Orea and Kumbhakar, 2004). The model assumes that there are a finite number of classes using different technologies and that each unit can be assigned to a particular group, using the estimated probabilities of class membership. Moreover, the number of different groups is also tested by the estimations.

Efficiency in energy is a theme that has attracted much research in recent decades (Farsi and Filippini, 2004; Kleit and Terrell, 2001; Knittel, 2002; Managi et al., 2006; Vaninsky, 2006). A review of the literature shows two main approaches: the DEA–data envelopment analysis (Arocena, 2008; Barros and Assaf, 2009; Nakano and Managi, 2008; Zhou and Ang, 2008) and the stochastic frontier models (Barros and Antunes, 2011; Barros and Managi, 2009; Barros and Peypoch, 2007, 2008; Hattori, 2002; Kopsakangas-Savolainen and Svento, 2011; Kuosmanen, 2012).

There are several motivations for the present research. First, prompted by growing evidence of the destructive impact on the planet of the excessive dependence on fossil-based fuels, competition among energy producers has induced the development of renewable energy sources to provide non-polluting forms of energy, in accordance with the Kyoto protocol (see Tol, 2010). This competition is reinforced by deregulation and is obliging the hydro-power companies to upgrade their plants' efficiency in order to gain greater market share (Barros, 2008).

Second, benchmarking is a way for hydro-power plants to manage their relative performance and is therefore a major issue of competitiveness management (Barros, 2008; Barros and Peypoch, 2007; Briec et al., 2011; See and Coelli, 2012). However, the modelling procedure

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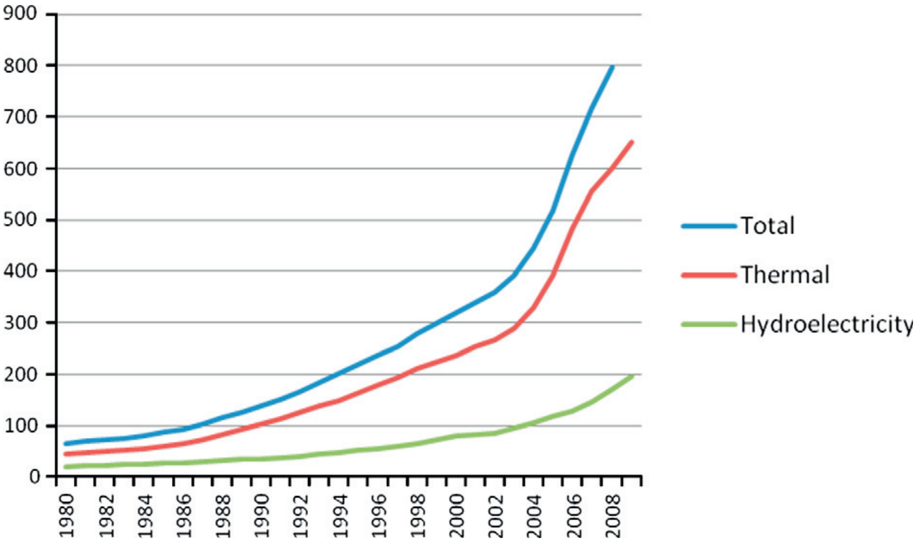

Sources: U.S. Energy Information Administration
Note: Only formainland China, not including data from Hong Kong, Macao and Taiwan.

Fig. 1. The installed electricity capacity of China (Million Kilowatts). Sources: U.S. Energy Information Administration. Note: Only for mainland China, not including data from Hong Kong, Macao and Taiwan.

adopted in this paper has not previously been applied to hydro-power plants.

Third, total factor productivity varies among hydro-power plants, based on their location, managerial practices and the resource specificity of the plants. As there are different strategic options to be found in the different units of an industry, because of mobility impediments, not all options are available to each hydro company, causing a spread in the efficiency scores of this industry. The resource-based theory (Barney, 1991; Rumelt, 1991; Wernerfelt, 1984) accounts for different efficiency scores in terms of heterogeneity of resources and capabilities on which the strategies of the hydro-power plants are based. These may not be perfectly mobile across the industry, leading to a competitive advantage for the best-performing plants.

Fourth, heterogeneous efficiency permits the definition of tailored energy policies for the units analysed, enabling the improvement of efficiency based on distinct policy prescriptions. Finally, although some papers focus on hydroelectric power plants (Ang et al., 2010; Barros, 2008; Barros and Peypoch, 2007; Briec et al., 2011; See and Coelli, 2012), this form of energy production continues to attract only limited research, despite its obvious importance as the most important source of renewable energy, taking into consideration the fact that in contrast to the wind and the sun, hydro-power can be produced 24 h of every day. Research in energy efficiency includes DEA models (Barros, 2008; Briec et al., 2011; Sueyoshi and Goto, 2011), stochastic frontier models (Barros and Peypoch, 2007; Growitsch et al., 2012; Huang et al., 2010; See and Coelli, 2012) and combined DEA and stochastic frontier models (Jaraitė and Di Maria, 2012).

With regard to Chinese energy efficiency, several papers have addressed this theme: Hu and Wang (2006), Chai et al. (2009), Wei et al. (2009), Shi et al. (2010), Wu et al. (2012), Zhou et al. (2012a) and Zhou et al. (2012b), Wang et al. (2012). However, no paper has focused specifically on hydro energy companies.

The present paper is organised as follows: the next section provides an account of the contextual setting; the methodology is then presented, followed by a section on the data and results; the final section offers a discussion of the findings and our concluding remarks.

2. Contextual setting

With China's rapid economic growth and the vast expansion of its manufacturing industry during the past three decades, the country's electricity sector has experienced a remarkable pace of development. China is currently ranked second in the world in terms of electricity production and consumption.

Its total installed electricity capacity surged from 65.87 million kilowatts in 1980 to 874.00 million kilowatts in 2009, the total electricity net generation rose from 285.47 to 3,445.99 billion kilowatt hours (see Figs. 1 and 2) and the total electricity consumption sharply increased from 261.49 to 3,657.47[1] billion kilowatt hours during the same period. Moreover, as the figures show, the Chinese power sector has continued to depend predominantly on thermal and hydro-generated electricity, despite the emergence of alternative sources, such as nuclear power, wind power, biomass and waste, solar, tidal and wave power. Whilst these green renewable sources are increasingly advocated, given the urgent need to reduce carbon gas emissions drastically, they collectively accounted for no more than 2.74% approximately of China's total net electricity generation in 2009.

Although some authors argue that the inadequate supply of electricity does not constrain China's economic growth (Shiu and Lam, 2004), shortages are still a common phenomenon that affects both residential consumers and industrial and commercial enterprises (Cherni and Kentish, 2007), as well as providing added impetus to those who seek reforms. Since 1978 and the enforcement of the "Reform and Open-up" policy proposed by Deng Xiaoping, various reforms have been introduced in the electricity industry, albeit slowly.

The most recent series of reforms is in progress, but remains to be completed (Yeoh and Rajaraman, 2004). Before 1985, the principal reform that was implemented in the electricity sector was the creation of an appropriate regulation authority by the Central Government. It should be taken into account that at that time, the Central Government played every fundamental role as the planner, investor, regulator, manager, and operator of the Chinese power industry (Yeoh and Rajaraman, 2004). In 1985, the State Council issued Central Document No. 72, aimed to encourage local governments and other enterprises to set up new electricity plants.

Later, the State Council planned to separate government functions from enterprise management within the electricity sector and established five regional power company groups. The government finally began to accelerate the reform process in 2002. In March, the

[1] This data is estimated from information provided by the China Electricity Council (www.cec.org.cn) and may not be consistent with the data from the EIA.