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Impact analysis of coal-electricity pricing linkage scheme in China based on stochastic frontier cost function

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HIGHLIGHTS

- This study evaluates the coal-electricity pricing linkage policy in China.
- Six stochastic frontier cost models are used to estimate efficiency measures.
- The coal-electricity pricing linkage scheme is a double-edged sword.
- We suggest the threshold value of 5% or group specific.

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ABSTRACT

This study evaluates the feasibility and fairness of 2012 amendment to coal-electricity pricing linkage policy in China. Our empirical design is based on several stochastic frontier cost functions and the results show that the amended pricing linkage scheme is a double-edged sword as follows. On the one hand, it provides incentives for less-efficient (with efficiency less than 90%) power plants to increase their efficiency. One the other hand, it imposes a penalty to highly-efficient power plants (with efficiency more than 90%). And even worse, the higher the efficiency is, the bigger the penalty will be. To make the current coal-electricity pricing linkage scheme more feasible, we suggest the threshold value of 5 instead of 10%, and a group specific threshold value instead of the current one-size-for-all practice.

1. Introduction

In December 2012, the State Council of China announced a new policy *"the guideline on thermal coal market reform"*, which states that when the price of thermal coal fluctuates by more than 5% over 12 months, thermal power plants are allowed to add 90% of the coal-price change into the pre-determined electricity pricing formula. However, the rest 10% price change has to be absorbed by the plants through cost saving, in order to prevent power plants from passing all the price change onto electricity consumers.

Upon the arrival of this new policy, we naturally respond with the following questions: How did regulators reach this 90/10% cost sharing proportion? Is this 10% fair enough for power plants? To answer these questions, this paper assesses the fairness and feasibility of the 90/10 cost-sharing proportion.

According to article 35 and 36 of *"the 1996 Electric Power Law of China"*, electricity price for both residential and non-residential users is subject to central government's cost-plus regulation. Specifically, for on-grid power price which is paid by transmission/distribution companies to thermal power generation plants, it is calculated as costs (including tax) plus the product of allowed rate of return and audited asset of power plants; for delivered power price paid by end users to transmission/distribution companies, beside costs and asset return, a certain amount of losses due to electric leakage are also allowed to be taken into account in the price-calculation formula. Before April 16, 2004, the cost of individual power plants used in price calculation is predicted cost of that plant, and under such a price regulation regime, power plants had no incentive to reduce costs, leading to much inefficiency and varied electric prices across power generation plants. To improve efficiency, the National Development and Reform Commission issued *"the Notice on Further Improving Power Generation Efficiency and Regulating Electric Price Management"* in 2004, and a yardstick based price regulation scheme took into place accordingly. To be more specific, for power plants established after April 16, 2004, the cost used to calculate on-grid power price is the average cost of power plants established in the same year

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and province, which should also stand for the most advanced technology in that province. The purpose of the new scheme is to distinguish government accepted costs from realized cost of individual plants to stimulate power plants to adopt advanced technology and lower operating costs. To support the new price regulation scheme, the National Development and Reform Commission of China declared the allowed on-grid power price (known as on-grid price benchmark) for different provinces at the end of 2004 for the first time. Because expenditure on purchasing coal accounts for a big fraction of the total cost of power plants, the benchmark on-grid power price should be linked with coal price. Out of that consideration, a coal-electricity pricing linkage scheme was introduced in 2004 which will be discussed in detail in Section 2.

The logic behind this research is quite straightforward. We suppose the deviation of observed costs from the minimum costs results from systematic error term as well as non-negative inefficiency, and then estimate the scale of inefficiency of each thermal power plant, if the results show that the cost inefficiency of most power plants is greater than 10%, then we can argue that the 10% cost-sharing proportion for power plants is appropriate and feasible, and not otherwise. In line with this research design, the stochastic frontier cost function analysis is regarded as the most suitable methodology to achieve our research purpose.

The rest of this paper is organized as follows. Section 2 introduces the coal-electricity pricing linkage scheme in China; Section 3 reviews the literature on cost efficiency estimation. Section 4 sets up the model for the analysis while Section 5 describes the panel data used in this research. Section 6 presents empirical results. Section 7 concludes and discusses policy implications and directions for future research.

2. Coal-electricity pricing linkage scheme in China

To stabilize electricity price and provide more incentive to coal mines to increase output, China's central government introduced the dual-track pricing scheme in coal industry in 1985, which requires that qualified coal mines sell a certain amount of thermal coal to qualified thermal power plants (usually large state-owned power plants) at a government-guided price. Output beyond the quota can be priced 50% or 100% higher and sold freely in the market [1]. In practice, when the gap between government-guided price and market price was big, the dual-track pricing scheme generally caused much tension between coal suppliers and downstream power plants. However, considering that cancelling the pricing regulation on thermal coal would undoubtedly lead to increase in electricity price, which is essential to the whole economy, the central government had hesitated to amend the dual-track pricing scheme in the past years. Recently, with continuous decline in thermal coal price since the financial crisis in 2008, China's central government finally decided to cancel the dual-track pricing system at the end of 2012 when the pressure from coal producers was building up.

In an economy where the electricity price is determined in the market, power plants will decide the direction and amount of change in electricity price when coal price changes. On the other hand, when electricity price is under effective control of the government and there is little room for power plants to further reduce costs (i.e., they are fully efficient), all changes in coal price should be added into the cost calculation formula. Japan is a suitable case in this aspect. First, its coal-electricity pricing linkage scheme is enforced in the retail sector of residential electricity consumption where the price of power sold by regional monopolies is subject to yardstick competition regulation. The scheme allows coal price changes of less than 30% to be covered in cost calculation because regulatory agency contends that power plants have no further capacity to absorb cost increase without harming their sustainable development. Second, in the sector of non-residential electricity consumption, such as for high voltage users, the electricity price is determined through the negotiation between suppliers and users, without government intervention [2].

In China, although power generation activity was separated from transition, distribution and sale sectors in 2002 and competition was gradually introduced into the power generation sector, prices of both residential and non-residential electricity are still regulated by a cost-plus mechanism. In order to link the benchmarking on-grid power price with the coal price in the market, China's government introduced a coal-electricity pricing linkage scheme characterized by cost-sharing between power plants and electricity users in 2004.

According to "the Guidance on Establishing Coal-electricity Price Linkage Mechanism" in 2004, the change rate of coal price more than 5% in more than 6 months will trigger the coal-electricity price linkage program. In this case, the change of the benchmark on-grid power price will be determined by

$$\Delta P_{power} = \Delta P_{coal} \times (1 - \alpha_{absorption}) \times \beta \times \frac{7000}{\lambda} \times \frac{(1 + 17\%)}{(1 + 13\%)} \quad (1)$$

where ΔP_{power}, ΔP_{coal} and $\alpha_{absorption}$ denote allowed change in the benchmark on-grid power price (CNY/kW h), real change in coal price (CNY/g) and self-absorption proportion of power plants, respectively. β is allowed value of standard coal consumption per kW h generated (g/kW h) which is declared by the government annually. And λ represents calorific value of coal used by individual power generation plants (calorie/g). Since China set 7000 calories per g coal as the calorific value of standard coal, $7000/\lambda$ converts different kinds of coal used by individual power plants into the standard coal. Before Jan 1, 2009, the value-added tax rate for coal was 13% and 17% for electricity. Thus, the term (1 + 17%)/(1 + 13%) was used to adjust the difference in tax rate, which is not necessary today since the value-added tax rate for coal has been increased to 17%.

Following the guidance of 2004, the self-absorption proportion of power plants was 30% which was reduced to 10% in 2012 according to *"the Guideline on Thermal Coal Market Reform of 2012"*. We would illustrate the coal-electricity price linkage program using an example as follows: in 2015, the declared value of standard coal consumption per kW h generated (β) was 318 g/kW h. Suppose that the price of coal with calorific value of 6000 calorie/g (λ) increased from 500 to 550 CNY/ton during the past 12 months which triggered the coal-electricity pricing linkage scheme. Then the price change in the benchmark on-grid power price will be calculated as $\Delta P_{power} = 0.00005 \times (1 - 10\%) \times 318 \times 7000/6000 = 0.016695$ CNY/kW h, that is, an increase of 50 CNY/ton in coal price will lead to a rise in the on-grid power price by 0.016695 CNY per kW h. *"The Guidance on Establishing Coal-electricity Price Linkage Mechanism of 2004"* also offered the calculation formula to link delivered power price to coal price as $\Delta P_{deliveredpower} = \Delta P_{ongridpower} * 1/(1 - \eta)$, where $\Delta P_{deliveredpower}$ and $\Delta P_{ongridpower}$ denote price change in delivered and on-grid electricity, respectively, and η is the allowed leakage rate during the transition and distribution process.

Furthermore, as asserted by electricity industry regulatory agency, an incentive-based regulation tool is embedded in the pricing linkage scheme mentioned above. That is, with a unified 10% cost absorbing, power plants turning out to be able to lower their cost through efficiency gain of 10% or more can enjoy the excess retained earning, whereas those who fail to achieve that will be punished with decreased retained earnings. With a purpose of having more retained earnings, power plant managers will do their