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Economies of scale and technological progress in electric power production: The case of Brazilian utilities

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ABSTRACT

This paper examined the cost structure of the electricity generation companies in Brazil during the period 2000–2010 by using a translog cost function that imposes no restrictions on production technology and allows for the existence of non-homotheticity. The hypothesis that economies of scale are a typical feature of the generation market in Brazil and, in general, are not exhausted at lower levels of production is not rejected. This result supports the vision that indivisibilities restrict efficiency gains from free-market competition in the Brazilian electricity generation and most of the last restructuring in the industry regulation was based on this assumption. Furthermore, over the sample period, technological progress led to cost reductions in electric power supply. These technological improvements take the form of both a neutral technological effect as well as a non-neutral fuel effect, which prevails over the capital and labor saving technical changes.

1. Introduction

Since the seminal paper by Christensen and Greene (1976), many other studies have claimed that economies of scale may not prevail in power generation or are exhausted at a much smaller scales. According to this view, the largest firms' cost advantages over the smaller firms are insignificant thus making this segment more prone to competition (Huettner and Landon, 1977; Goto and Tsutsui, 2008). Technological and economic factors are consistent with those findings.[1] Besides the fact that the largest plants may have higher maintenance and reserve requirements costs as well as higher forced outage, technological advances in electricity transmission, by expanding the number of potential buyers for small firms, also contribute to reduce the economies of scale and hinder market concentration in power generation. Finally, the reduction of the minimum efficient size of modern generation technologies along with the lead-time for the completion of generating plants increased the potential for competition in this segment of the electricity market. Corroborating those views, regulatory reforms are promoting the development of open markets for electric power and encouraging competition among firms in order to boost efficiency (Wolak, 1997; Joskow, 1997).

Nevertheless, as the industry is being reshaped to increase the role of competitive market forces, the structure of the electric power industry in many countries, with a few utilities retaining a significant share of the market, may counteract the movement towards more competition in this industry. Moreover, the literature reports that for the larger firms, the installed capacity is still based on technologies characterized by indivisibilities. Their higher efficient production levels provide them with the advantages of natural monopolies, where economies of scale prevail on the relevant output range (Hisnanick and Kymn, 1999; Berry and Mixon, 1999).

The tradeoff between enforcing competition and benefitting from economies of scale in the power supply industry is also present in the discussion among those who advocate the vertical integration of the electricity industry and the prevalence of larger firms (Joskow and Schmalensee, 1983; Kaserman and Mayo, 1991; Nemoto and Goto, 2004) and the defenders of unbundling (Gilsdorf, 1994). The former allude to the significance of economies of scope and scale whereas the latter point out the benefits of divestiture and competition. Hence, a relevant issue to investigate is how the industry will react to this new

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[1] Kamerschen et al. (2005) highlight the effect of technological factors in the reduction of the concentration in the power supply industry.

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environment, characterized by those contradictory forces, particularly with respect to the efficient scale of operation for individual firms. Indeed, if the efficient scale requires a substantially higher (lower) production than the output levels of most firms, the number of utilities in the industry will decline (increase) and competition will be weakened (enhanced). In a post-deregulation world, this question is better addressed by appraising the production levels that exhaust economies of scale in the power generation industry. Here, the analysis of economies of scale and technological progress are important issues to be investigated.

The above mentioned issues are particularly relevant for the Brazilian power supply industry in which firms are engaged in a nationwide competition, made possible by the extension of the electricity transmission system (Trindade, 2012). Although dominated by hydroelectric power plants, which account for 77% of the installed capacity in 2010, an increasing role is given to thermoelectric companies that are responsible for 19% of the aforementioned capacity, with the remaining 4% provided by other technologies such as wind power (Empresa de Pesquisa Energética, 2011). Moreover, different sizes of utilities coexist in this industry. However, it is not clear if it is better to generate electricity in small or medium sized firms or in a few, bigger utilities with many plants. To address this issue, the measurement of costs and economies of scale is crucial to evaluate the performance of the Brazilian power supply with respect to its ability to provide a reliable supply of electricity at competitive prices.

Our study contributes to this debate. Its objective is to examine the cost structure of the electricity generation utilities in Brazil. To achieve this objective, a flexible translog cost function is used for 21 firms during the period 2000–2010. Particular emphasis will be given to the analysis of the minimum efficient scale for different utility sizes. Furthermore, the paper will investigate substitution possibilities among inputs and the impact of technological progress on the Brazilian power supply industry.

The paper proceeds as follows. Section 2 briefly describes the regulatory framework in Brazil. Section 3 presents the methodology used to estimate the cost structures for electricity generating utilities in Brazil while Section 4 describes the data and the variables used in the translog cost function. Section 5 discusses the econometric results and investigates the possibilities of input substitution in this segment of the electricity market. Section 6 estimates the economies of scale and discusses the efficient scale. Section 7 discusses technological progress for the utilities analyzed. Finally, Section 8 summarizes the main conclusions.

2. Power supply industry in Brazil: the regulatory framework

In Brazil, the electricity industry,[2] following the pattern of the international restructuring of this economic activity, has substantially changed over the last two decades. This restructuring started in the mid-1990s and was anchored in an extensive privatization program. The reform was intended to foster competition in the generation segment and to break-up the vertical integration in the industry (Santana and Oliveira, 1999; Ramos-Real et al., 2009). The underlying supposition behind this reform was the idea that the gains from competition would outweigh the losses of economies of scale and de-verticalization.

The incentives to competition and “unbundling” required regulation and coordination structures that were provided by two institutions: the Electricity National Agency (ANEEL) and the National Electricity System Operator (ONS). The former mediates conflicts between the agents in the industry, prevent and fine opportunistic behaviors, whereas the ONS coordinates supply and demand interconnected by the national transmission network. The power suppliers cannot, *a priori*, deliver their production to a given customer in this network; they control only the electricity they add to the transmission system and, equivalently, the consumer cannot choose a specific supplier, selecting only the energy taken from the network. When matching demand and supply, the ONS identifies lower cost producers, directing demand, instantaneously towards those suppliers; whenever this match diverges from previous contracts between producers and consumers,[3] financial compensations are settled by the Power Commercialization Chamber (Pinto et al., 2007; Carpio and Pereira, 2007).

The electricity rationing schemes implemented in 2001–2002 demonstrated that previous reforms were not sufficient to adjust the power supply to a rapid demand growth. In 2005, a new cycle of regulatory changes was introduced to cope with the power shortage. Among the elements of these reforms, two distinct market environments were created: the Regulated Contract Market (ACR) and the Free Contract Market (ACL).

The main change of the 2005 reform was the creation of ACR regulated market, which represents a step back in the move to a more competitive model pursued by the 1990s' reforms. This market was inspired by the “single-buyer” model where an entity buys all electricity from producers and sells it to distributors. Here, the ANEEL collects the distribution utilities' electricity demands and acts as the single buyer, so that the aggregated demand of these companies – instead of the individual ones – is brought to the power suppliers. Bilateral contracts traded in the ACR market have up to a 5-year horizon for the physical delivery of electricity. The price that prevails in this market is defined by auctions organized by the regulatory agency.

Notice that the segmentation into free and regulated markets brought about by the 2005 reform is based on the assumption that indivisibilities in electricity generation are significant enough to justify the aggregation of the electricity demand. This intertemporal aggregation through the regulated market may lead to welfare gains because it reduces the firm's transaction costs. This aggregation allows, for example, the firms, especially the largest ones, to make a single contract to sell their whole output instead of writing separated (and costlier) sale contracts with each of their many buyers. Furthermore, the ACR market, by assuring that firms have minimum contracted sales for up to a 5-year period, reduces their business risk for both, small and larger firms.

The Free Contract Market (ACL) market deals with final electricity consumers (companies, electro-intensive manufacturers, etc.) that individually demand substantial amounts of electricity (in comparison to households and small business); contracts established in this market are not mediated by the regulatory authority (ANEEL). The ACL works as a back up to the regulated market, filling the gaps between predicted demand and supply in the ACR market. Moreover, the free market: (1) provides electricity for consumers unable to access the power transmission and distribution network, or large final consumers, which are not willing to pay the costs of these infrastructures and respective regulations; and (2) is a useful information source about electricity scarcity (for private and government agents), since the long term contracts in ACR may be unable to reflect sharp changes in the supply and demand balance.

3. A translog cost function for power supply utilities

Since the seminal work of Christensen and Greene (1976), there has been an increasing interest in the identification of the factors that determine electricity costs such as scale of operation, type of ownership, vertical integration, and competition at the different stages of the electric power industry. These factors are best analyzed by using a cost function.

Because of its flexibility and convenient properties – it imposes no restrictions on production technology and accommodates non-

[2] This industry is composed of three markets: i) the electric power generation, where the electricity producers operate; ii) the transmission market, whose network transports electricity through long distances in high voltages and; and iii) the distribution market, which transports electricity in low voltages to the final consumers. The focus of this paper is the first market.

[3] In other words, when the producer provides to the consumer more (or less) electricity than the previous amount specified contract.