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Successful Brazilian experience for promoting wind energy generation

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ABSTRACT

This paper reviews the Brazilian experience with support mechanisms to promote renewable energy generation, from feed-in tariffs in the early 2000 s to the current auction process, with a focus on wind energy generation. Brazil's original and innovative approach includes investment coordination mechanisms that have reduced risks enough to make wind energy a viable option.

1. Introduction

Brazil is a large country with regard to continental distances and its sizable power system, both in terms of generating capacity and grid extension. A prominent feature of the Brazilian power system is the significance of its hydropower, which accounts for more than 85% of the generation in the interconnected system (Ons, 2018), similar to that of Canada or Norway. Moreover, most hydro capacity in Brazil is associated with large reservoirs that work as energy regulators (Araújo et al., 2008; Harris, 2006). The transmission system has more than 100,000 kilometers of lines that operate at 230 kV and above.

This high share of hydropower energy is a natural hedge for wind power producers, as the rain period ends at the beginning of the wind period, i.e., when it rains, the wind is not blowing, and vice versa (Bittencourt et al., 1999). Wind energy, besides contributing to seasonal stabilization of the hydro-dominated Brazilian electrical system, can also play a valuable role in reinforcing the grid ends and in reducing power transmission losses (Dewi, 2001). However, the participation of wind generation in the Brazilian electric system is still not representative, with an installed capacity of just over 6 GW, less than 5% of Brazilian installed capacity (Aneel, 2015) and only 2% of the country's wind power potential (Abeeólica, 2012). However, this scenario has been changing since 2009, when the first wind generation randomness mitigation method in energy procurement auctions was introduced. Wind power has experienced an exponential and virtuous growth in Brazil. From 2009 to 2014, 14 GW in new projects was contracted. Such projects will raise the volume of wind power installations in the country to 17.8 GW by 2019, more than two times larger than the current capacity, and will attract more than US$ 30bn in investments (Abeeólica, 2012).

This study investigates the effect of wind generation randomness mitigation methods in boosting the growth of wind generation, making it the main source of the expansion of generating capacity in Brazil. Although the subject of Brazilian electricity reforms has been addressed in some articles (Rego, 2013; Rego and Parente, 2013; Mendonça and Dahl, 1999; Jannuzzig, 2005; Dutra and Menezes, 2005; Lock, 2005; Melo et al., 2007; Araújo et al., 2008), this study presents new analysis about the growth of wind power as an energy source in the country.

2. Wind energy competitive auctions

The Government of Brazil (GoB) created two very interesting (and similar) accounting processes for the electricity generated by wind farms in order to mitigate this risk of wind power randomness, with annual and quadrennial adjustments, one for each type of procurement auction. In both cases, annual production variations between 90% and 130% of the contractual obligation are accepted. At the end of each four-year cycle, positive or negative accumulated variations are financially settled. These methods, described in the next section, allow wind energy to compete with other sources, such as hydropower and biomass.

The Brazilian electric sector (Law 10848/2004) has two electricity trading environments: a regulated contracting environment (RCE) and a free contracting environment. In the former, distributors purchase electricity from generators through publicly regulated procurement auctions. In the latter, independent consumers and generators can directly negotiate bilateral contracts. RCE procurement auctions are one-sided, i.e., only generators (sellers) bid, and the winners are those sellers who bid the lowest electricity price. There is a "single buyer" – a government company that is simply a short-term coordinating intermediary between producers and distributors (Araújo et al., 2008). Distribution companies, or a single buyer acting on their behalf, aim to

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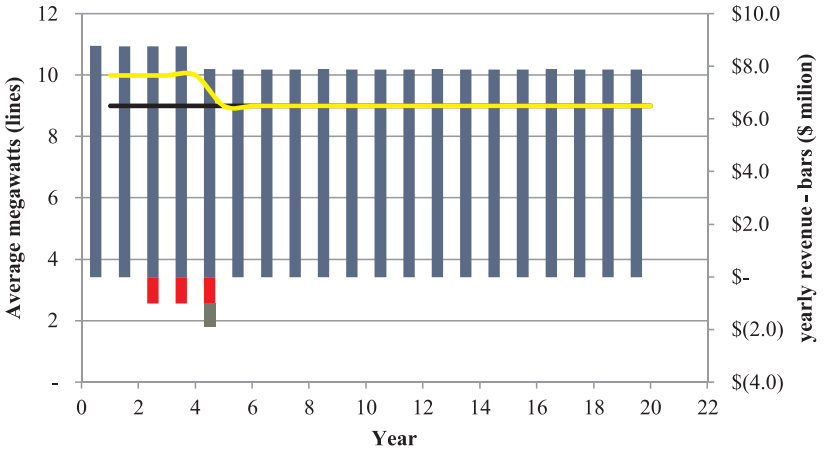

Fig. 1. GBA auction wind contract when generation is below energy contracted.
Source: Authors
Legend:
Blue bar: Contract's yearly revenue ($ million)
Red bar: Yearly financial adjustment ($ million)
Green bar: Financial adjustment of the quadrennial 9$ million)
Black line: Electricity generated (Average MW)
Yellow line: Electricity's contractual obligation of the current quadrennial (average MW)

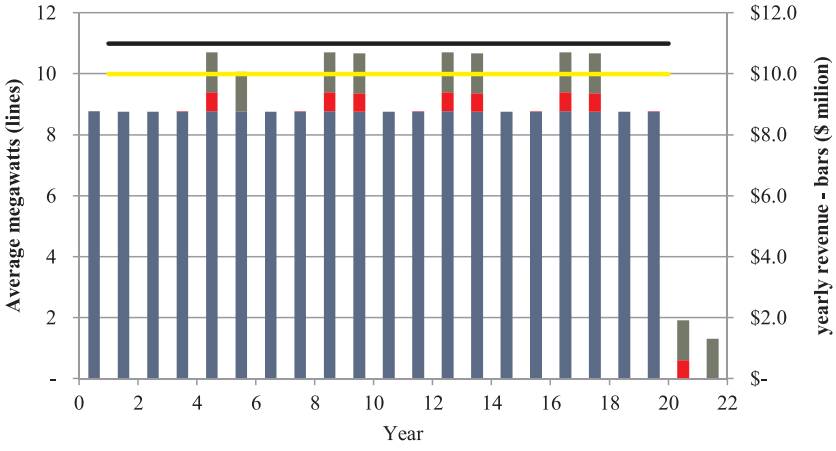

Fig. 2. GBA auction wind contract when generation is over energy contracted.
Source: Authors
Legend:
Blue bar: Contract's yearly revenue ($ million)
Red bar: Yearly financial adjustment ($ million)
Green bar: Financial adjustment of the quadrennial 9$ million)
Black line: Electricity generated (Average MW)
Yellow line: Electricity's contractual obligation of the current quadrennial (average MW)

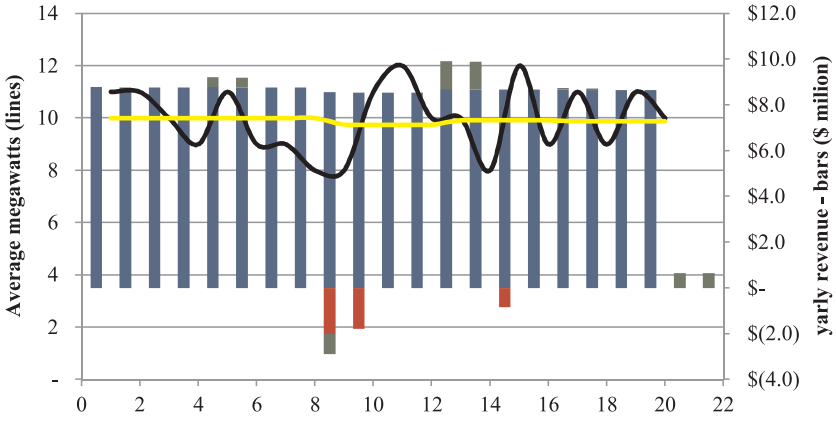

Fig. 3. GBA auction wind contract with random wind power generation.
Source: Authors
Legend:
Blue bar: Contract's yearly revenue ($ million)
Red bar: Yearly financial adjustment ($ million)
Green bar: Financial adjustment of the quadrennial 9$ million)
Black line: Electricity generated (Average MW)
Yellow line: Electricity's contractual obligation of the current quadrennial (average MW)

"outsource" the supply of electricity to meet their market requirements. The utilities are responsible for the demand forecasts; each one declares to the auctioneer (the "single buyer") the electricity demand it wishes to contract. They sign PPAs with IPPs, which are in charge of building a power plant and delivering electricity by a certain date. The fundamental difference from centralized procurement is that the government does not provide payment guarantees, nor does it take a contractual position in the market (Maurer and Barroso, 2011).

With the single procurement buyer, when the price is considered high, the auctioneer is allowed to buy less electricity than is necessary for the load growth so as to achieve a price that is as low as possible, a decision that is not to be expected from distribution companies. Contract bids in these auctions are for periods of 20 years to wind power plants. The long-term energy contracts were created to attract investment in generation, in a country with high load growth (Araújo et al., 2008). Long-term contracts also have the effect of reducing the incentives for generation companies to manipulate output and prices in spot markets (Pittman; Zhang, 2010). In addition, according to Arellano (2003), the theoretical and empirical literatures show that the more a generator's capacity is contracted forward at fixed prices, the less incentive a firm has to manipulate the spot market and the closer the outcome is to that of a competitive market.

Besides, in 2008, the GoB created another type of auction in order to create supply surplus: the Government Buyer Auction (GBA). In this auction, a government company, the Chamber of Electric Energy Commercialization (CCEE by its Portugese acronym), signs power purchase agreements (PPAs) with independent power producers (IPPs). This is a typical centralized procurement in which the government