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Efficient power generating portfolio in Brazil: Conciliating cost, emissions and risk

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HIGHLIGHTS

- We use portfolio theory to evaluate Brazilian generation mix expansion.
- The Brazilian expansion plan is evaluated in three CO_2 price scenarios.
- It is room to efficiency gains through portfolio diversification.
- When CO_2 is not priced, fossil fuel increases it shares in the efficient portfolio.
- High CO_2 prices increase the share of wind and biomass in the mix.

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ABSTRACT

The main purpose of this paper is to assess efficiency of the Brazilian electricity generation mix proposed in the 2020 Decennial Plan for Energy Expansion (DPEE 2020). It evaluates estimated costs, risks and CO_2 emissions following the mean–variance portfolio theory. The efficiency frontier is estimated for three CO_2 prices scenarios: no CO_2 prices, low CO_2 price and high CO_2 price. The planned portfolio in Brazil presented in the DPEE 2020 is relatively close to the efficient frontier, however there is still room for risk mitigation by diversifying the energy portfolio. As there is currently no CO_2 price in Brazil, the tendency is that diversification increases fossil fuel share in the energy mix, but the introduction of a CO_2 price can be an option to promote renewables. This type of large general market framework can contribute to reduce market uncertainties by reducing the level of government's discretionary activism.

1. Introduction

The Brazilian electricity generation mix is characterized by the predominance of hydropower that currently represents 79% of total generating capacity. However, the share of hydropower is expected to decrease over the next decade due to environmental constraints on the remaining hydro potential. A relevant goal of the Brazilian energy planning is to maintain current share of renewable energy sources in the generation mix, which account for 84%. Other planning objectives are to minimize the cost of the generation portfolio and improve security of supply. To pursue these objectives, Brazilian government has a 10-year plan indicating the expected evolution of the generation portfolio: the 2020 Decennial Plan for Energy Expansion (DPEE).

At present, it is widely accepted that the diversification of the Brazilian generation mix is not a policy choice, but mainly a result of the restrictions on the hydropower potential. Thus, one of the most important policy objectives is to prioritize the renewable generation in the diversification process for the generation mix. However, this policy has not been very successful as a significant amount of non-renewable projects has been selected by the power auctions in the regulated market (fuel oil, coal and natural gas).

One can say that there are two main research questions regarding the current Brazilian electricity policy. First, how efficient (in terms of cost and risk) is the DPEE?; second, what is the feasibility of DPEE upon considering the relative cost of the different generation sources? The main purpose of this paper is to assess the current situation and the energy policy objectives proposed in the DPEE, taking into account the average cost and the

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risk associated with the different electricity generation alternatives available.[1] Our analysis follows a set of studies that applies the mean–variance portfolio theory (Markowitz, 1952; Merton, 1972) to evaluate the efficiency of electricity generation mix (Awerbuch and Berger, 2003; Roques et al., 2008; Marrero and Ramos-Real, 2010 ; Delarue et al., 2011).[2] We use the estimated efficiency electricity generation frontier for Brazil to evaluate the 2020 plan and aim at indicating the opportunities for improving the efficiency of the government planning.

Another important energy policy challenge is the reduction of CO_2 emissions. To study this issue, the paper also evaluates the impacts of difference scenarios of CO_2 prices in the efficient generation portfolios. Since Brazilian generation portfolio depends on the competition between different generation sources, this exercise can indicate the impacts of different price scenarios for CO_2 on the evolution of generation electricity portfolios in Brazil.

This paper is divided into five sections, after this introduction. Section 2 is dedicated to discuss the energy planning in Brazil. This section presents the characteristics of the Brazilian power sector's institutional framework and the characteristics of the 2020 energy plan. Section 3 describes the methodology used in the paper to estimate the efficiency frontier for the power generation portfolio in Brazil. Section 4 shows results on average cost and risk estimates for the alternative technologies considered. Section 5 presents and discusses the estimated efficiency frontiers, evaluates the 2020 plan and proposes how to achieve better results in terms of average cost and risk. This analysis is made for the different scenarios of CO_2 price considered. Finally, Section 6 concludes and discusses the implications for the electricity policy in Brazil.

2. Electricity energy planning in Brazil

2.1. The structure of Brazilian electricity industry

There are three main characteristics of the Brazilian power system: (i) it is a continental-sized interconnected system; (ii) electricity consumption increases fast and continuously; and (iii) hydro power generation is the predominant source of generation.

Brazil has an interconnected electric system able to supply the main consumption centers (Fig. 1). This system provides 98% of the national electricity consumption, totaling 415 TW h in 2010 (EPE/MME, 2011).[3] Interconnection has historically been motivated to exploit hydroelectric potential located far from consumption centers and to take advantage of complementarities between regional hydrology. So, if there is a drought in one region, hydro generation in the others can compensate it. The interconnected grid allows the operation of an integrated electricity wholesale market in Brazil.

After electricity rationing in 2001, Brazilian electricity consumption has raised 4.5% a year. As per capita consumption is still quite low (2.370 kW h/year), a sustained growth can be expected in the long term. It creates a necessity for a continuous expansion of generating capacity. Hydropower plants (large and small) correspond to 79% of the system's 110 GW (Fig. 2).[4] As many plants share the same river basin, most of the decisions are interdependent. The Brazilian hydro-electric plants count on reservoirs with great storage capacity that operates in a multi-annual scheme.[5] Brazilian hydro reservoirs can store half of the annual electricity consumption in Brazil.

Other renewable sources are present in the Brazilian generation mix. Biomass represents 4% of total installed capacity. Most of it corresponds to cogeneration plants in sugar and ethanol mills that use sugarcane bagasse as fuel. Wind power represents only 1% of total capacity, but its share is increasing at a rapid pace as there are about 7 GW under construction. As renewable share is high (84%), the power sector is not a relevant source of CO_2 emissions in Brazil.

Natural Gas is the most important fossil fuel, with 8% of total installed capacity. Its share increased sharply after the power rationing in 2001. This trend stalled when political changes in Bolivia implicated uncertainty in Brazilian gas supply. Oil products and coal stand for only 6% of generating capacity. The two nuclear plants account for 2% of the mix.

2.2. Institutional organization in Brazilian electricity industry

After the power rationing in 2001, the institutional reshape of the Brazilian electricity sector was an electoral commitment of Lula's government. The new regulatory framework was implemented in 2004. This reform aimed at ensuring a new supply crisis would not happen and avoiding the rise of electricity prices (Losekann, 2008). In order to do that, the government took back the planning of the sector and changed the wholesale market implemented during the liberalization process in the 1990 s (Losekann, 2008).[6]

EPE (Energy Research Company, in English) was established to assist the Energy Minister on sector planning and Aneel (Electricity Regulatory Agency) to organize the auctions in order to acquire new generation capacity. Two market environments were created for contracting electricity in the wholesale market: regulated market environment (RME) and free market environment (FME). Distribution companies buy electricity in public auctions at the RME. They submit demand projections in a five-year horizon to EPE. Based on those projections, EPE sets the total amount of electricity to be acquired in the auctions. The electricity price is defined by the bids of generation companies. The lower price projects win the auctions. The model distinguishes the energy coming from already existing plants ("old energy") of the energy that comes from the new ones ("new energy"), being both negotiated in the RME at different levels. The old energy was oriented to respond to the existing market at the moment when the model was created. The "new energy" is turned to expansion of the distribution market.

At the FME, large consumers[7] are free to choose their suppliers outside the centralized auctions. The energy is negotiated through bilateral contracts with generators and traders. The contracts last for different periods, and short-term contracts are predominant.

Even though there is no carbon charge in Brazil, the Brazilian energy policy incentives renewable power sources. PROINFA (Incentive Program to Alternative Sources of Electricity) program was implemented in 2002 to promote small hydro, bagasse and wind power plants. It was feed-in tariff scheme, where Eletrobras offered long-term contracts (20 years) with different prices for each source. As the new model for the Brazilian power sector was implemented, the mechanism to promote renewables changed to auctions dedicated to alternative sources.

[1] Following the related literature, risk refers to uncertain cost to generate electricity, and not to the supply risk resulting in the inability to generate electricity [Awerbuch, 2006]. Nevertheless, both concepts are highly related [Wiser et al., 2004].

[2] For a recent application of the mean–variance theory for a producer trading energy on the electricity market in Brazil, see De Oliveira et al. (2011).

[3] The rest is supplied by isolated systems, located mostly at Amazon region. Those systems have progressively been interconnected to the national system. EPE predicts that they will soon account for only 0.4% of total consumption.

[4] It considers the Paraguayan part of Itaipu power plant that is allocated to the Brazilian market.

[5] Water can be stored to respond demands over a year ahead.

[6] Ramos-Real et al. (2009) and Tovar et al. (2011) analyse the effect of the new regulatory framework on efficiency and productivity of the electricity distribution companies.

[7] Consumption higher than 3 MW.

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