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Diversifying the Brazilian electricity mix: Income level, the endowment effect, and governance capacity

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ABSTRACT

Low and middle income countries are usually trapped by their natural resource abundance, and thus have little opportunity to diversify their electricity matrix. On the other hand, in high income countries, new electricity sources have been growing faster, regardless of their resource endowments. As income grows, countries should have more opportunities to develop new technologies. Thus, the evolution of technologies to generate electricity should lead to a new mix of fuel consumption along the steps of an imaginary electricity ladder, from the more traditional to the more advanced and cleaner technologies. Notwithstanding the income effect, the endowment effect could hinder the diversity of electricity sources. In this context, we examine whether or not Brazil has been able to diversify its electricity mix with respect to income growth, by breaking what we called the "endowment trap". Based on an economic model developed in this research, we found evidence that Brazil has succeeded in breaking its hydroelectric dependency, but has not eliminated the polluting sources.

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1. Introduction

In low and middle income countries, economic growth is typically related to the exploitation of abundant natural resources [1–5], which are generally the cheapest and most accessible alternatives. We see a similar pattern in the electricity industry: the evolution of the electricity mix frequently depends on the energy resource endowment [6,7]. If these countries present a high potential for hydroelectric power or have important reserves of oil and coal, usually there are no investments in developing other electricity sources. They are caught in what we call the "endowment trap." In these cases, their economic growth is strongly based on their resource endowments. As a result, there are risks of stagnation caused by the depletion of natural resources. From that perspective, electricity mix diversification is an alternative way to improve energy security, and can be achieved by breaking the endowment trap.

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[8–10]. For example, this is the case with the development of solar and wind power in Northern Europe when compared to more tropical countries, in which the natural conditions would be more appropriate to foster these energy sources. We note that high income countries, whose capital, skills, and governance capacity (which is defined as the degree of predictable, open, and enlightened policy-making) are abundant, have started to mitigate the endowment trap in the last quarter of the twentieth century. In this positive environment, new technologies could bloom while energy security risk is decreased.

In order to determine if Brazil is trapped by its natural resource endowments, we analyzed the endowment and income effects, and correlated these perspectives. Our goal is to determine if economic growth is capable of breaking the endowment trap in the Brazilian electricity matrix, taking into account the governance capacity. To do this, we developed an endowment trap model based on an existing model of the energy ladder. Also, we empirically applied the developed model to determine if there is a relationship between shifts in the electricity mix and income for the case of Brazil.

The remainder of the paper is organized as follows. In Section 2, we describe the background of the endowment trap and the energy ladder concept, two frameworks that we used in our study. In Section 3, we present an overview of the electricity mix in the world and in Brazil. By analyzing the changes in the electricity mix, it is possible to identify trends, including the increased use of certain energy sources such as natural gas, nuclear, and wind power. In Section 4, we describe our theoretical model, which relates the increasing use of certain sources in the electricity matrix to income growth and resource endowment. This theoretical approach inspires our empirical model, in which we isolate the endowment effect and determine if Brazil has broken the endowment trap, as other countries have done in the past. The model results are presented in Section 5. In Section 6, we summarize our conclusions and some related implications.

2. Background

Our method is based on two frameworks: (i) the endowment trap, and (ii) the energy ladder concept. Both frameworks converge to the same point of view: high income could bring more options with which to diversify the electricity mix. However, from the perspective of the endowment trap, this benefit could only be achieved if a country breaks the trap. This is not an easy task, especially for low and middle income countries, as described below.

2.1. The endowment trap

The relationship between income and endowment is not new, and has been called “the endowment paradox” [11] or “natural resource trap” [12–14]. Prebisch [13] and Singer [14] demonstrated that developing countries with high levels of endowments did not diversify their industrial segments. These countries became exporters of primary products and importers of manufactured products. The reason is that low income countries “underperform” their endowments; i.e., they explore their natural resources in an ineffective fashion, whereas high income countries “overperform” due to a technology-oriented approach.

Many studies treat the endowment as a condition that must be overcome. Collier and Venables [15] explain that African countries have high potential for hydrocarbons, hydroelectric power, and solar power. However lack of capital, skills, and governance capacity make the new green energy options very expensive in comparison to traditional sources. Hence, the development of new green technologies is constrained, and traditional options of energy still remain the major sources of power.

Corroborating that view, Liu et al. [16] conclude that the utilization of energy sources relies largely on local resource endowment. In China, straw and firewood have been widely used in provinces where they are abundant. However, Fan et al. [17] show that in rural areas in China, new kinds of energy technologies have been developed regardless of their energy endowment, especially small hydroelectric power plants, wind power, and solar power. The use of new renewable sources to break the coal trap was established by the so-called Brightness Program, as reported by Hevia [18]. This was a challenging program that brought electricity to rural villages in China.

Haberl et al. [19], in a study of biomass, affirm that countries with a large resource endowment can achieve higher per capita biomass production levels. On the other hand, the authors explain that countries with a small resource endowment have other means at their disposal to achieve higher consumption; i.e., more efficient production and trade.

Efficiency seems to be a key factor in overcoming the use of traditional sources, but it requires capital to invest in research and development, and training. Without specific policies to foster new technological development, low income countries with energy endowments do not have the means to diversify their electricity mix. If they have high reserves of traditional fuels and underperform with respect to the use of their endowments, diversifying the energy matrix could be too expensive for them.

2.2. The energy ladder concept

The energy ladder concept posits that in response to higher income, the population of a country will shift from traditional biomass to more modern and efficient fuels.

Some studies used the energy ladder concept to explain the experience of a country, as Kroon et al. [20] have shown. For example, Goldemberg [21] suggests that income growth is linked with better access to more advanced technologies. Under these circumstances, consumers have the option to shift to more efficient, convenient, and cleaner energy systems throughout the energy ladder.

Reddy and Reddy [22] show that with increased household income in India, wood and coal are being displaced by liquefied petroleum gas (LPG) and electricity, as predicted by using the energy ladder concept. Another study by Reddy [23] highlights that in India, the country's urbanization process allowed the supply of more advanced technologies. Factors such as difficulty in storing lower-step energy sources, and an increasing the availability of more sophisticated and convenient energy sources from urbanization such as kerosene, LPG, and electricity, have helped households climb to the highest steps. According to Reddy's results, which are based on multilogit models, this transition fundamentally depends on income. However, societies become more egalitarian over time, and the energy ladder concept based on income could vanish.

Arseneau [24] used an econometric exercise to show that with increasing per capita GDP, a country reduces the use of lower quality and more polluting fuels (e.g., coal and peat). Then, it begins to use oil products, natural gas, and electricity. An econometric exercise by Jakob et al. [25] also shows that developed countries with high economic growth rates can shift toward more efficient energy sources.

Grübler [26] describes a progression of the energy matrix mix, and highlights nuclear energy. As a country develops, it uses more modern renewable sources and nuclear power, with higher yields. However, Marcotullio and Schulz [27] show that this progression is influenced by the energy resource endowment in each country,