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## Energy development potential: An analysis of Brazil

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## HIGHLIGHTS

- This paper deals with the spatial dimension of the Brazilian energy sector.
- We construct an index of the energy development potential for Brazilian states.
- Energy issues are defined over time and space, thus have spatial dimensions.
- The spatial results show that there are two well-defined spatial patterns.

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## ABSTRACT

This paper develops an indicator for the energy development potential (EDP) of 27 Brazilian states. This indicator uses data on a state's infrastructure and its supply of and demand for energy. The indicator measures the data for three periods: the first part of the 1990s, which is a period of low economic growth; the first part of the 2000s, which is a period of high economic growth but with a historical crisis in the Brazilian energy sector; and 2009–2011, which is a period of economic growth after the energy crisis. Using a factor analysis, we are able to identify three factors for EDP. They are the demand for energy, the supply of renewable energy, and the supply of nonrenewable energy. We use these factors to classify the Brazilian states according to their EDP and to perform an exploratory spatial data analysis (ESDA) by using the Moran indicators and the local indicators of spatial association (LISA).

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## 1. Introduction

Modern economies rely heavily on energy consumption. As a result, energy is an important and vital input in the development process of a country and plays a major role in achieving economic, social, and technological progress. Therefore, population growth, economic activity, sector development, and industrialization should dictate an increase in energy demand and the need for an increase in the supply of this input. Thus, the diversification of the energy matrix in a region makes the region less susceptible to crises and better able to meet, without damage, the growing worldwide demand for this input (Fan and Chia, 2011; Chen and Lin, 2008).

Pinto Junior (2007) affirms that energy is an essential input for the economic and social organizations of all countries, and the process of energy production and consumption has an impact on the development of these organizations and the environment.

Therefore, energy has a prominent role in the formulations of business strategies and government policy agendas.

Several studies exist that deal with the energy issue. Some studies focus on the demand side of the problem. Rapanos and Polemis (2006) estimate the determinants of residential energy demand in Greece. The residential consumption of energy depends on the characteristics of the countries that might have a relation to their climatic conditions. Their paper gives a better understanding of some of the determinants of energy demand. According to the authors, these determinants are the real gross domestic product (GDP), the real price of energy, and the number of heating degree days. According to the literature, energy demand and consumption issues also relate to the final demand in non-energy sectors (Kagawa and Inamura, 2001, 2004), the dynamic changes in expected socio-economic structures and temperatures (Hekkenberg et al., 2009), technology effects (Zhang et al., 2011), structural changes (Kagawa and Inamura, 2001, 2004), past consumption trends (Ito et al., 2010), development stages (Fan and Chia, 2011), and energy use patterns and economic structures (Kahrl and Roland-Holst, 2009).

In terms of the energy supply of a specific region, the following variables are relevant: variables related to the infrastructure of production, transportation, storage, and distribution as well as

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geographical factors; for example, the presence of oil reserves, natural gas, coal, and river flows. Besides these variables, Sola et al. (2006) add the actions of states and governments that seek not only to fund the sector but also to encourage alternative sources of energy and technology mainly through investments in research and development (R&D).

Recently, the incorporation of the spatial dimension into applied economic modeling has increased in the literature. This trend is occurring because the spatial aspects of some questions can make a crucial difference in an analysis and therefore can have policy implications. Most of this type of analysis with spatial data occurs in the fields of regional economics and economic geography. But, nowadays the spatial models are being used for a wide range of applied economic topics (Burnett, 2011). According to Burnett (2011, pp. 01),

...this makes sense given that energy resources, energy consumption, and energy production are defined over time and space, and therefore have spatial dimensions. Examples include patterns of energy use across space, spatial linkages between energy and the environment, spatial spillovers in regional energy consumption, spatial clustering in fossil fuel exploration activities, spatial structuring of electricity prices, etc.

Our work is motivated by the economic growth observed in Brazil that leads to an increase in the domestic demand for energy and the heterogeneous spatial structure of the production and consumption of energy in its various sources. Therefore, we evaluate the energy issue in the context of the states in Brazil, that is, as a spatial phenomenon.

Few studies exist that address the energy sector in Brazil in a spatial dimension. The uniqueness of this article increases its importance and differentiates it from others. This paper proposes a study that comprises different sources of energy in all of Brazil's states. The heterogeneous spatial dimension of the recent Brazilian economic development and the large discrepancies among Brazilian regions reinforce the importance of this kind of study. Thus, the article has implications for the discussion on the differentiated policies for the energy sector among the Brazilian states.

Therefore, we build an indicator for the energy development potential (EDP) of the 27 Brazilian states by analyzing the supply capacity and energy consumption of each of these units. In addition, we seek to assess how this potential is distributed in the country. The analysis focuses on three different periods: the first part of 1990s in which there is low economic growth, the first part of 2000s in which there is high economic growth but with a historical crisis in the Brazilian energy sector, and 2009–2011 in which there is economic growth after the energy crisis. The analysis implemented in this paper considers the periods after the 1990s because of, in part, the modifications implemented by the Brazilian government in respect to its energy agenda.

The following aspects are the highlights of Brazil's energy agenda: the development of an infrastructure through market forces that leads to a reduction in the state's share of new enterprises and also in terms of energy policy, the reduction of fiscal (i.e., taxes) resources and the increases in taxes and fees paid by energy companies, the necessity for energy firms to find new sources of primarily private funding, changes in the industrial organization of both the fossil fuel and electric energy sectors from monopoly companies, and the promotion of the widespread use of natural gas.

We use a multivariate analysis in this study, more precisely a factor analysis, to construct the EDP indicator for each Brazilian state. Furthermore, we use an exploratory spatial data analysis (ESDA) by observing the Moran indicators and the local indicators of spatial association (LISA) for the territorial analysis of the results.

This paper is organized as follows. The second section presents a brief characterization of the Brazilian energy policy and structure. The third section presents the database and describes our method. The fourth section presents the results, and the fifth contains some conclusions.

## 2. Brazilian energy profile

### 2.1. The Brazilian energy policy: A brief overview

The key assumption in all energy policies up to the 1980s was that the energy industry represented a sector of the infrastructure with peculiarities that were central to the economy: strong economies of scale that often led to monopolies and oligopolies, capital intensity, and long maturity terms that required special treatment and an active presence from the government. This view began to be challenged with the rise of another view that governments needed to address the majority of the problems faced by industrial economies as well as those under development. The peculiarities of the energy sector were greatly exaggerated and began losing importance because of the changes in technology. Thus, based on this new viewpoint, energy began to be seen as a commodity equal to others.

Therefore, based on the earlier ideas before the 1990s, the energy policy and the energy infrastructure in Brazil were established mainly through the role played by the Brazilian state. An example is the development of the electricity and petroleum sectors from 1945–1990. The petroleum sector was developed after the creation of Petrobrás S/A in 1951. Petrobrás was responsible for the reduction in the importation of petroleum. In the early 1960s, the geographical distribution of the refineries was concentrated in the Bahia (BA), Rio de Janeiro (RJ), and São Paulo (SP) states.

The development of the electricity sector began with private capital such as LIGHT S/A in the 1930s, and then state capital made major investments in generation and the transmission of energy between 1950 and 1970. The creation of Eletrobrás changed the system. Eletrobrás acted as a holding company in the electricity sector through direct control or as a minor partner. The creation of Eletrobrás quickly changed the ownership structure of the sector by expanding public funding and reducing private funding and the weight of self-production. The result was the construction of an integrated national system that covered almost 80% of Brazil, except in the northern region and the construction of hydroelectric plants.

In the beginning of the 1990s, the system based on government investments collapsed, mainly because of the decrease in the growth path and in the use of public tariffs to control inflation. Thus, the energy policy in Brazil changed direction. In the electricity sector, a privatization movement started along with the creation of a regulatory agency (ANEEL) with a national system controller (ONS). The new policy agenda was based on the following aspects: the end of an equalized rate; the de-verticalization of the production chain—the separation of the generation, transmission, distribution, and the sale of electricity; the privatization of the generation and the distribution by Eletrobrás and several states; and the building of a regulatory framework. In the 2000s, the construction of various hydroelectric and thermoelectric plants took place.

### 2.2. The Brazilian data set

Using the National Energy Balance (BEN) published by the Ministry of Mines and Energy, we observe an increase in the demand and supply of energy in Brazil. The final demand for

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