

# Household consumption of electricity in Brazil between 1985 and 2013



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## HIGHLIGHTS

- Brazilian residential electricity sector.
- Special Features and structure of the residential electricity consumption.
- Representation and modeling of electrical energy consumption.
- Elasticities consumption-tariff; consumption-income; consumption- households.

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## ABSTRACT

This article describes the electricity consumption in Brazilian residences between 1985 and 2013 through linear regressions. The explanatory variables considered were the number of households, effective consumption of families as a proxy for family income, and electricity tariff for households. To deal with the power generation crisis of 2001 we have introduced a dummy variable in the form of a step function. With such explanatory variables, we were able to account for the reduction of household electricity consumption caused by the policies conducted in 2001 and their permanent consequences. The regression presented coefficient of determination of 0.9892, and the several statistic tests conducted assured the existence of long-term relation between the electricity consumption in residences and the explanatory variables. The obtained elasticities for the household consumption of electricity with respect to number of residences, family income and residential tariff of electricity were  $1.534 \pm 0.095$ ,  $0.189 \pm 0.049$ , and  $-0.230 \pm 0.060$ , respectively. These results allowed understanding the evolution over time of the household consumption of electricity in Brazil. They suggest that the electric sector in Brazil should pursue an active policy to manage demand of residential electricity using tariffs as a means to control it.

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## 1. Introduction

The electricity consumption in residences is normally explained by economic factors such as economic activity, family income, electricity tariffs and those of its substitutes, environmental conditions, increasing population, number of residential units, etc. (Nakajima and Hamori, 2010; Achão and Schaeffer, 2009; Sa'ad, 2009; Ghisi et al., 2007; Narayan et al., 2007; Halvorsen and Larsen, 2001; Jannuzzi and Schipper, 1991). Other explanatory factors relate to changes in life style, public policies, climate and regional conditions, etc., that induce new behavior, habits and basic needs (Wiesmann et al., 2011; Achão and Schaeffer, 2009; EPE, 2007; Jannuzzi and Schipper, 1991; Ghisi et al., 2007; Halvorsen and

Larsen, 2001). Most models reported in the literature consider family income, electricity tariffs, and other complementary factors or explanatory variables which the authors consider important to explain its behavior.

For Portugal, a model to describe the electricity consumption in residences included as complementary explanatory variables the household area, persons per household, weather conditions and many other factors (Wiesmann et al., 2011). For the G7 countries, a similar model considered as important complementary variables natural gas tariff, the ratio between electricity and natural gas tariffs, price of home appliances, and ambient temperature. The relatively high magnitudes of the elasticity with respect to electricity and natural gas tariffs suggested their potential use to control residential electricity demands (Narayan et al., 2007). For Norway, the authors considered as important complementary variables the environment temperature, price and number of electric home appliances. They identified as causes for the increase in household electricity intensity the greater use of appliances and

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larger home areas, while changes of consumer habits were considered without impact on it (Halvorsen and Larsen, 2001).

For Brazil, Achão and Schaeffer (2009) identified as important complementary factors affecting the residential consumption the number of households and the household electricity intensity. Factors such as the country's regions and income levels that could be associated with different habits or behaviors had smaller impact on the residential electricity consumption (Achão and Schaeffer, 2009). Other important factors were the inclusion of low-income populations as consumers under the universalization policy of electricity consumption, and availability of easy credit conditions for the consumers with the consequent increase in their ownership of electrical appliances (Achão and Schaeffer, 2009; EPE, 2007; Jannuzzi and Schipper, 1991; Ghisi et al., 2007).

To describe the behavior of the consumption of residential electricity through explanatory variables one usually use linear regressions to estimate technical coefficients or elasticities. The choice of explanatory variables or factors are also limited by the availability of data for the analyses (Nakajima and Hamori, 2010; Sa'ad, 2009; Narayan et al., 2007; Gujarati, 2000).

This work aims at identifying the important factors or explanatory variables that influenced the consumption of residential electricity in Brazil between 1985 and 2013, and obtain elasticities from linear regressions with respect to them. To understand the recent evolution of the household consumption of electricity we construct scenarios assuming different evolution of explanatory variables. This article starts presenting the structure of the electricity consumption in the country, and the data and methods used in this study. It follows with results and discussions, with an attempt to understand the recent evolution of the residential consumption of electricity in Brazil, and finally with conclusions and policy recommendations.

## 2. Structure of the electricity consumption in Brazil

The total electricity consumption in Brazil is still small compared with of developed countries; the total electricity consumption was 2.94 MWh/person in 2011 while in developed countries it was between 5 MWh/person and 24 MWh/person (EPE, 2012). The residential electricity consumption is expected to increase in Brazil in the coming years to accommodate economic growth and improvements on the level of human development of Brazilian society (EPE, 2012). In 2013 it represented 26% of the total electricity consumed in the country with an average growth rate of 4.9%/year between 2003 and 2012 (EPE, 2014).

The structure of electricity consumption in Brazil is presented in Fig. 1. The residential sector, responsible for 26% of electricity consumption in 2013, has grown faster than the other sectors due to several factors including the increasing intensity of household electricity consumption through utilization of home appliances.

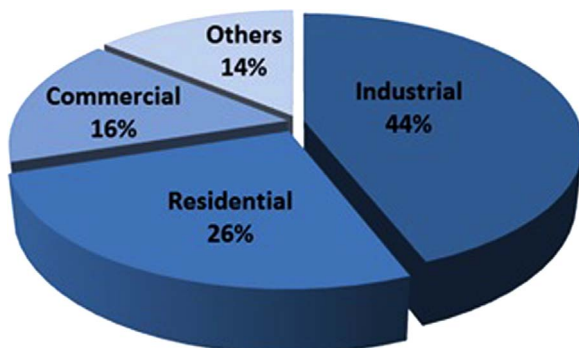


Fig. 1. Structure of the electricity consumption in Brazil in 2013 (EPE, 2014).

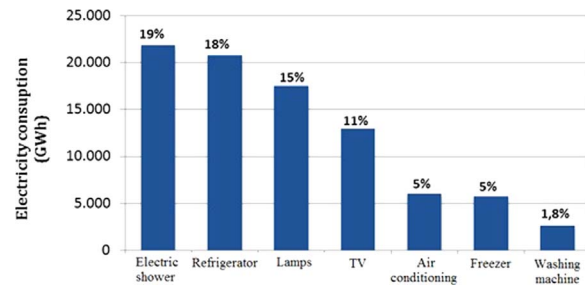


Fig. 2. Main appliances found in Brazilian households in 2012. The share of each appliance with respect to the total residential consumption is presented above each bar EPE (2012).

Fig. 2 presents the main appliances responsible for electricity consumption in a typical Brazilian home in 2012. Electric showers are an important consumption appliance in the country, and its presence decreased slightly over the last 10 year (EPE, 2014). The use of air conditioning devices, including those with reverse cycle to provide cool and hot air as desired, is currently growing very fast in the country and may soon reach the third position regarding electricity consumption. These observations tend to indicate that greater family income has been an important factor to determine the electricity consumption in Brazil.

## 3. Methods and data

In this work we try to explain the household electricity consumption behavior in Brazil in a top-down manner through explanatory variables, expressed in time series, using linear regression based on the ordinary least squares approach (Gujarati, 2000). This approach furnishes elasticities relating the electricity consumption in residences to the explanatory variables. The typical variables considered in such approaches are income and tariffs. To perform the regressions and statistical tests we employed the EViews 8 software (IHS Global, 2013). Econometric theory is used to evaluate the stationarity of the time series, their order of integration and possible cointegration to verify if there are meaningful causal relations between the explanatory variables and the electricity consumption in residences.

On the other hand we use a bottom-up approach to survey specific data and factors, that may have influenced the household consumption of electricity in Brazil during 1985 and 2013, to identify a broader and more meaningful set of explanatory variables (Wiesmann et al., 2011). To do that we undertake a literature review analyzing possible factors and present it in Section 3.2. below. With meaningful elasticities, we discuss the results, and attempt to explain the current evolution of the residential consumption of electricity in Brazil. Specifically, we make some projections for the coming years attempting to understand the impact of the explanatory variables on it.

### 3.1. Regression model

The functional form to describe electricity consumption is somewhat arbitrary. Although there is no consensus about the best functional form, many studies consider multiplicative or logarithmic models. We adopt such a model for the analysis of residential electricity consumption,  $E_t$ , i.e.,

$$E_t = b_0 \prod_{i=1}^N X_{it}^{\varepsilon_i} e^{u_t} \quad (1)$$

where  $X_{it}$  is the explanatory variable at time  $t$ ,  $b_0$  and  $\varepsilon_i$ ,  $i = 1, \dots, N$ , are coefficients to be determined, and  $u_t$  is a residue. The coefficients  $\varepsilon_i$  are interpreted as elasticities and defined as

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