The Long-Run Elasticity of Residential Energy Demand: Evidence from Geographical Regions

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Resumo

Compreender a demanda de longo prazo dos consumidores aos preços da energia elétrica é essencial para regulamentações eficientes do mercado, decisões de planejamento de fornecedores e avaliação de políticas econômicas para o desenvolvimento econômico do país. As elasticidades de longo prazo da demanda residencial de energia são estimadas para as cinco regiões geográficas do Brasil: Norte, Nordeste, Centro-Oeste, Sudeste e Sul, com frequência mensal de janeiro de 2003 a junho de 2015. Para estimar as elasticidades de longo prazo utilizamos um modelo econométrico dinâmico considerando as restrições de cointegração. Os resultados evidenciam que a elasticidade-preço a longo prazo é inelástica para cada região geográfica e que a região mais sensível a variações de preço é a região sul.

Palavras Chaves —Eletricidade, Demanda, Elasticidade, Longo prazo, Regiões

JEL: C13, C22, C52

Abstract

Understanding consumers' long-run response to electricity prices is essential for efficient market regulations, supplier planning decisions, and evaluation of economic policies for the economic development of the country. The long-run elasticities of residential energy demand are estimated for the five geographic regions in Brazil: North, Northeast, Midwest, Southeast and South, with monthly frequency from January 2003 to June 2015. We use a dynamic econometric model in a cointegration setup in order to estimate the long-run elasticities. We find that long-run price-elasticity is inelastic for each geographic region and that the region most sensitive to variations in price is the South.

Keywords—Electricity, Demand, Elasticities, Long-run, Regions

JEL: C13, C22, C52

I. INTRODUCTION

Electricity is obtained from many energy sources and supplied to consumers via complex system, divided into three steps: generation, transmission and distribution. Brazil has plentiful water resources and the main source of the nation's electricity is hydropower. Electricity generation in Brazil in 2015 had the following breakdown[1]: hydraulic (61.9%); natural gas (13.7%), biomass (8.2%); petroleum derivatives; (4.4%), coal and derivatives (3.3%); nuclear (2.5%); wind (3.7%); and others (2.3%).

Electricity supply is segmented by classes of consumers, among which the principal are residential, industrial and commercial. In the period analyzed (2003-2015), there was little variation in the relative shares of the consumption classes, with averages of 43% by the industrial class, 25% by residential consumers, 17% by commercial users and 15% by other consumers. The residential segment is very important, since it is the second largest in terms of demand and is subject to strong influence of price fluctuations. The economic theory associated with the behavior of this type of consumer suggests that demand is generally more elastic to prices in the long term in relation to the short run (Topel and Rosen (1998), Athukorala and Wilson (2010)). Residential consumers face resistances from some factors, such as replacement of durable goods and consumption habits that can take years to respond completely to price changes. This makes the response of demand to prices in the long run to significantly exceed the short-term response.

The main objective of this work is to estimate the long-term price elasticity of residential demand for electricity in Brazil, segmented by the five official geographic regions – North, Northeast, Midwest, Southeast and South – during the period from January 2003 to June 2015. The investigation of the price elasticity is relevant for the electric power sector, where the actors make long-run decisions. For market regulators, forecasts of this elasticity are essential for the design of mechanisms and support for efficient allocation. For generators and distributors, optimized investment in capacity and infrastructure requires precise predictions of the long-range response of demand to changes in prices. In relation to policymakers, knowing the price elasticity is vital to measure demand for electricity and direct investments for the economic development of the country. Therefore, estimating the long-run price elasticity can help generators, distributors and regulators make wise decisions about public policies for the electricity sector.

In this study we also estimate the long-run elasticity of demand to income, which measures the percentage variation in demand in relation of a change in income of consumers. We consider the influence of other variables on residential demand, such as the total index of manufacture of electrical machines, apparatuses and materials and the index of appliance prices. We also note that a part of the observed variation in prices is driven by specific events that affect demand in large geographic areas, such as during exceptionally hot summers. On the other hand, since the country's electricity is predominantly hydric, the variation in precipitation can affect the energy price. Therefore, we consider the exogenous variables temperature and rainfall.

A. *Related Work*

Various studies have examined residential energy demand functions using cointegration techniques to estimate the long-run elasticities. The results and implications of these studies obviously depend on the econometric methods applied, the frequency of the data, the development stage of a country or region and the type of variables considered. Generally they are based on aggregated variables of price and income along with some additional factors, such as climate or

[1] National Energy Balance (BEN) for 2016, base year 2015.

urbanization. We can mention the works of Athukorala and Wilson (2010) for Sri Lanka, De Vita, Endresen, and Hunt (2006) for Namibia; Narayan and Smyth (2005) for Australia; Galindo (2005) for Mexico; Kamerschen and Porter (2004) for the USA, and Beenstock et al, (1999) for Israel. Athukorala and Wilson (2010) investigated the short-term dynamics and the long-run equilibrium relations between residential electricity demand and factors that affect its behavior for the economy of Sri Lanka. Using annual data for the 1960-2007 period, they demonstrated that a long-run relation exists and found a long-run price elasticity of -0.62. Vita, et al. (2006) used data for the Namibian economy from 1980 to 2002 and the autoregressive distributed lag (ARDL) bounds testing approach to cointegration to estimate the long-run energy demand elasticities. With inclusion of some exogenous variables such as temperature, they found a long-run price elasticity of -0.34. Galindo (2005) estimated the demand for electricity in Mexico for different types of consumption in the 1965-2001 period. He found a small long-term price elasticity, of around -0.2. Narayan and Smyth (2005) estimated the long- and short-run elasticities of residential demand in Australia. The results showed a long-term elasticity of demand of -0.541 and short-term elasticity of -0.263. Kamerschen and Porter (2004) investigated the electricity demand for the residential and industrial classes in the United States in the period from 1973 to 1998. Using a simultaneous equations model, they found long-run elasticity between -0.85 and -0.94 for the residential sector. Beenstock, et al. (1999) estimated demand in Israel using two dynamic models with cointegration restrictions and found that "the long-run price elasticity of demand is -0.194 and -0.202" respectively. Other works related to this research are Achicanoy and Jimenez (2015), Dicembrino and Trovato (2013), Gonzalez et al (2012), Jiménez (2015), MohammadZadeh and Masoumi (2010) and Zadeh and Masoumi (2010).

The literature for Brazil in this respect is sparse. We can mention the study of Schmidt and Lima (2004) and Irffi and Catelar (2009) as the most important. Schmidt and Lima (2004) estimated the price elasticity in the 1963-2000 period using annual data and concluded that the long-run elasticity of demand for the residential class is -0.15. Irffi and Catelar (2009) estimated the residential, commercial and industrial demand for electric energy in the Northeast of Brazil during the period 1970-2003. They found that the demand is inelastic to price, with a value of -0.68.

In this article, we contribute to the literature in two ways: bringing new evidence for residential demand in Brazil with monthly frequency data and estimating the long-run elasticities in a disaggregated analysis in five geographic regions of Brazil. We also identify the effects of rain and temperature on demand. The results show that demand is inelastic to price, as found by studies in other countries, and that the region most sensitive to variations in price is the South.

II. METHODOLOGY

A. *Demand model*

The general form of the residential demand equation is:

$$d = d(p, V, u)$$

Where d is average consumption of electric energy, p is the marginal electricity price, V is a vector of all other relevant variables and u is a disturbance term. Residential demand for electricity is driven by the individual needs of household members, whose level of consumption depends on variables such as prices and income. We propose the following model to describe this demand:

$$d_t = kp_t^{\alpha}\tilde{y}_t^{\theta}e_t^{\gamma}l_t^{\delta}exp(u_t), \quad k > 0, \alpha < 0, \theta > 0, \delta < 0 , \gamma > 0 \tag{1}$$

Where:

d_t : is the electricity consumption at time t;
p_t : is the tariff (price) of electricity at time t;
$\tilde{y}_t$: is the average household income at time t;
e_t: is the index of production of machines and apparatuses at time t; and
l_t: is the price of electrical appliances time t.
u_t: is the disturbance term in time t.

We use a modified residential electricity demand model in neperian logarithmic form. Taking the logarithm in equation (1), we have a linear demand equation:

$$\text{Log}d_t^i = Logk_i + \alpha_i \text{ Log}\, p_t^i + \theta_i \text{Log}\, \tilde{y}_t^i + \gamma_i \text{ Log}\, e_t^i + \delta_i \text{ Log}\, l_t^i + u_t \tag{2}$$

or expressed as $D_t^i = K_i + \alpha_i\, P_t^i + \theta_i\, Y_t^i + \gamma_i\, E_t^i + \delta_i L_t^i + u_t$. We use equation (2) to estimate the demand function. We add the sub-index i to identify a model for each of the five regions of the country: North, Northeast, Midwest, Southeast and South.

B. *Econometric model*

Some caution needs to be taken to estimate the long-run relationship with non-stationary time-series data. The treatment in this case leads us to deal with the series with first differences before any estimation is done. The major problem with this procedure, however, is that by taking the first differences, the low frequencies are eliminated from the data, leaving only one model capable of explaining the short-term relationships. In this paper, we argue that since energy prices and real income appear to be non-stationary processes, econometric modeling of energy can be successful through cointegration analysis with error correction. Consider a Gaussian vector autoregression of finite order p, VAR(p):

$$y_t = \phi_1 y_{t-1} + \phi_2 y_{t-2} + \cdots + \phi_p y_{t-p} + \varepsilon_t \tag{3}$$

where y_t is a vector of n first-order integrated I(1) and endogenous variables, $\phi_i = 1, \ldots, p$ are matrices of dimension $n \times n$ and $\varepsilon_t \sim Normal\,(0, \Omega)$, $E(\varepsilon_t) = 0$, $E(\varepsilon_t \varepsilon_\tau) = \{\Omega, se\ t = \tau$ and $0_{n\times n}$, if $t \neq \tau\}$; where Ω is not singular. The model (1) can be written equivalently as:

$$\Pi\,(L) y_t = \varepsilon_t \tag{4}$$

Where $\Pi\,(L) = I_n - \sum_{i=1}^{p} \phi_i L^i$ is a polynomial matrix in L, and L represents the lag operator. Furthermore, $\Pi\,(1) = I_n - \sum_{i=1}^{p} \phi_i$ when $L = 1$.

The demand can be represented by a VAR(p) model with $n = 5$ stacked variables in the vector $y_t = [D_t\ P_t\ Y_t\ E_t\ L_t\,]'$. Considering the polynomial transformation $\Pi\,(L) = \Pi\,(1)L + \Pi^*(L)\Delta$ in the VAR(p) model given by equation (4), where $\Delta \equiv (1 - L)$, we can rewrite it as:

$$\Delta y_t = -\Pi\,(1) y_{t-1} + \sum_{j=1}^{p-1} \Gamma_j\, \Delta y_{t-j} + \varepsilon_t \tag{5}$$

Equation (5) is known as the vector error correction model (VECM) or error correction model (ECM). The parameters of the first-difference variables represent the short-term components, whereas the parameters of the variable in level (y_{t-1}) denote the long-run coefficients.

c.1 Long-run restrictions (cointegration)

The following hypotheses are assumed:

Assumption 1: The (n × n) matrix $\Pi\,(\cdot)$ satisfies:

1. $rank(\,\Pi\,(1)) = r, 0 < r < n$ such that Π (1) can be expressed as $\Pi\,(1) = -\alpha\beta'$, where α and β are (n × r) matrices with full column rank r.
2. The characteristic equation $|\Pi\,(1)| = 0$ has $n - r$ roots equal to 1 and all others are outside the unit circle.

Assumption 1 implies that y_t is cointegrated with order (1, 1). The elements of α are the adjustment coefficients and the columns of β span the cointegration space. Decomposing the polynomial matrix $\Pi(L) = \Pi\,(1)L + \Pi(L)\Delta$, where $\Delta = (1 - L)$ is the difference operator, a vector error correction model (VECM) is obtained:

$$\Delta y_t = \alpha\beta' y_{t-1} + \sum_{j=1}^{p-1} \Gamma_j\, \Delta y_{t-j} + X_t{}'\varphi + \varepsilon_t \tag{6}$$

where $\beta' = -\Pi\,(1)$, $\Gamma_j = \sum_{s=j+1}^{p} \phi_s$ $(j = 1, \dots, p-1)$ and $\Gamma_0 = I_n$. If we add m exogenous variables, X_t, in equation (3), equation (5) can be expressed as equations (6), where φ is a vector of $m \times 1$ dimension. For instance, if rainfall (rain) and temperature (temp) are add in model, X_t is defined as $X_t' = [rain_t, temp_t]'$. So, we can obtain the long-run elasticity from long-run relationships $\beta' y_{t-1}$ by estimation of the ECM. By normalizing the cointegration vector in D_t^i and considering a constant in the cointegration vector, we can denote the deviations from long-run equilibrium for each region i as:

$$\beta_i{}' y_{t-1}^i = (K_i, -1, \alpha_i, \theta_i, \gamma_i, \delta_i) \cdot \left[1, D_{t-1}^i, P_{t-1}^i\,, Y_{t-1}^i\,, E_{t-1}^i, L_{t-1}^i\,\right]' = -u_{t-1}^i$$

$$D_{t-1}^i = K_i + \alpha_i\, P_{t-1}^i + \theta_i\, Y_{t-1}^i + \gamma_i\, E_{t-1}^i + \delta_i L_{t-1}^i + u_{t-1}^i \tag{7}$$

Where u_{t-1}^i represent the deviations from the long-run equilibrium.

C. *Database*

The series of average consumption (D_t), in MWh, and the electricity tariff (P_t), in R$[2], were obtained from the National Electric Energy Agency (ANEEL). The index of appliance production (E_t) was obtained from the Brazilian Institute of Geography and Statistics (IBGE). For the price of appliances in time (L_t), we use the Comprehensive Consumer Price Index (IPCA), also computed

[2] Brazil's currency is the Real (R$). Over the study period of this paper, the exchange rate with the dollar fluctuated in an interval between approximately R$1.56/US$ and R$ 3.97/US$, with a rough average of R$ 2.28/US$.

by the (IBGE), as a proxy. The average household income (Y_t) was also obtained from the IBGE, based on the Monthly Employment Survey (PME). The average rainfall series was obtained from the company Della Coletta Bioenergia. Notice that capital letter indicates variables expressed in logarithm. Finally, the mean temperature series was obtained from the National Institute of Meteorology (INMET). Figure 1 shows the graphs of aggregate residential demand. It can be seen that the region with the highest consumption is the Southeast. The demand in each region is associated with its wealth. The Southeast is the richest and most populated, covering the states of Espírito Santo, Minas Gerais, Rio de Janeiro and São Paulo.

Figure 2 shows the average price by region. The price of electricity generally increased in the period analysed, with a particularly large increase in 2015, due to increase in rates in reaction to the low reservoir levels caused by the shortage of rainfall in 2014.

Fig. 1. Residential consumption by region

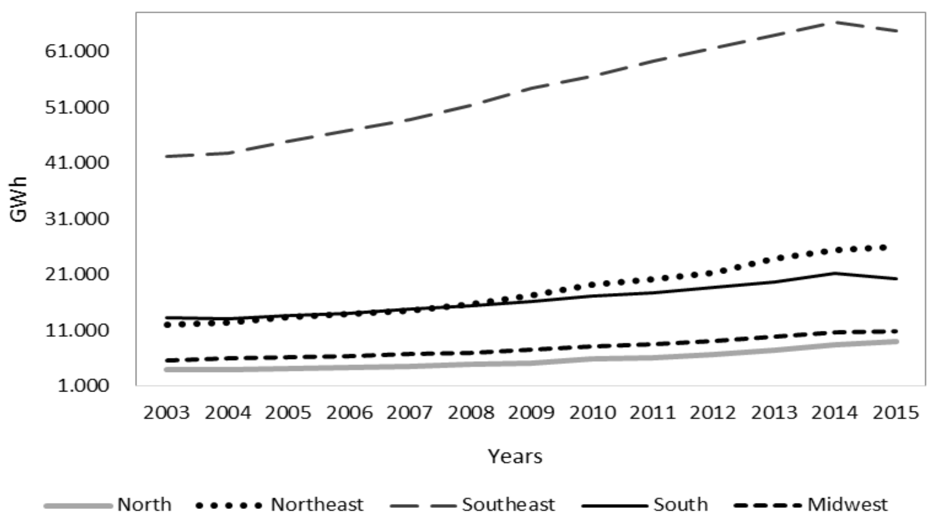
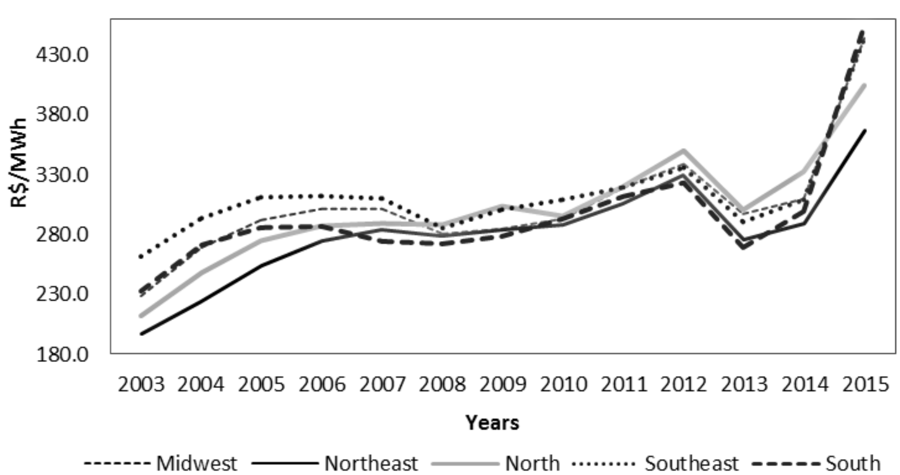


Fig. 2. Average price by region



III. EMPERICAL ANALYSIS

A. *Unit root tests*

The vector y_t in equation (1) is defined as of n first-order integrated I(1). So, we proceed to unit root test. Table I reports the results of these tests. The results show the presence of unit roots in the series on demand (D_t), price (P_t) and income (Y_t) in all the regions. The variables E_t and L_t also have a unit root[3], as do all the variables that compose the vector $y_t = [D_t\ P_t\ Y_t\ E_t\ L_t\ ]'$, i.e., $y_t \sim I(1)$. Hence, the first condition is satisfied. The next step is to test the existence of a long-run relation of these variables. For this purpose, we identified the order of lags of the VAR(p) model according to the Akaike, Schwarz and Hannan-Quinn information criteria. The results show that $p = 1$ for all the regions.

TABLE I. UNIT ROOT TESTS

Regions	Variable	PP-Test(4) *t-Statistic*	KPSS(5) *t-Statistic*
Midwest	Dt	-0.6097	1.4147 ***
	ΔDt	-25.9129 ***	0.2041
	Pt	-0.1735	0.9991 ***
	ΔP_t	-8.5020 ***	0.1857
	Y_t	-0.5483	1.4508 ***
	ΔY_t	-14.8599 ***	0.1898
Northeast	Dt	0.4776	1.4302 ***
	ΔDt	-21.6310 ***	0.2318
	Pt	-13.992	1.1808 ***
	ΔP_t	-9.4658 ***	0.0799
	Y_t	-0.5945	1.4484 ***
	ΔY_t	-14.3954 ***	0.1842
North	Dt	0.0284	1.3781 ***
	ΔDt	-15.9069 ***	0.1838
	Pt	-11.464	1.2617 ***
	ΔP_t	-11.2123 ***	0.0484
	Y_t	-0.1075	1.4412 ***
	ΔY_t	-13.6034 ***	0.2011
Southeast	Dt	-8.4737 ***	1.4949 ***
	ΔDt	-30.7166 ***	0.1823
	Pt	0.1357	0.5809**
	ΔP_t	-7.6958 ***	0.2313
	Y_t	-0.1075	1.4404 ***
	ΔY_t	-14.0789 ***	0.2040
South	Dt	-4.6973 ***	1.4416 ***
	ΔDt	-24.3386 ***	0.1468
	Pt	0.6232	0.8133 ***
	ΔP_t	-7.7375 ***	0.2547
	Y_t	-0.2029	1.4467 ***
	ΔY_t	-14.4135 ***	0.2116

Note: (1) We chose the constant as the deterministic component. Significance levels of 0.01, 0.05 and 0.10 are represented by ***, ** and *, respectively. Δ indicates the first difference of these variables. (4) We used the method of Newey-West with the Bartlett

[3] The results are not reported here due to space limitations, but we can present them upon request. The unit root tests for the exogenous variables temperature and rainfall are in appendix.

kernel for bandwidth. (5) the null hypothesis test indicates the stationarity of the series. Variables Y_t, E_t and L_t are also tested. Results are not reported in this table, but they are avaliables upon request.

The statistics λ-trace and λ -max of the cointegration test of Johansen (1998) and Johansen (1990) are presented next. The results of the λ-max test reveal the existence of a cointegration vector in each region. By incorporating the long-term dynamic in the effort correction model (ECM), we estimated the long-run elasticities of demand to price and income.

TABLE II. COINTEGRATION TEST

Regions	Hypothesized Number of r	Eigenvalue	λ Trace	λ Max
Midwest	$r = 0$	0.4568	129.427*	90.931*
	$r \leq 1$	0.1829	38.496	30.099
Northeast	$r = 0$	0.3558	117.109*	65.528*
	$r \leq 1$	0.1691	51.581*	27.5929
North	$r = 0$	0.3252	96.2744	58.597
	$r \leq 1$	0.1277	37.6774	20.359
Southeast	$r = 0$	0.4419	115.355*	86.304*
	$r \leq 1$	0.1105	29.0514	17.3326
South	$r = 0$	0.5150	145.479*	107.815*
	$r \leq 1$	0.1438	37.664	23.137

Note: In all cases, the max-eigenvalue test indicates one cointegrating equation at the 0.05 level. * denotes rejection of the hypothesis at the 0.05 level.

B. *Resultads of the long-run elasticities*

Table III presents the estimated long-run elasticities of demand to price and income. It can be observed that demand is inelastic in relation to electricity price and also to income. The majority of the coefficients related to price are not statistically significant. This implies that the long-run elasticity is perfectly inelastic. Despite this, some insights can be obtained through these results. In relation to income, most of the regions had statistically significant parameters. Moreover, the demand is only elastic in the North region. This means it is more sensitive than in the Midwest, Southeast, Northeast and South regions. This behavior of sensitivity of demand in function of income variations can be explained by the need to operate devices incorporated in people's lifestyle. Another explanation can be attributed to the increased acquisition of electrical and electronic appliances with rising income, requiring households to consume more electricity to use them. Observation of the values estimated in relation to the regions provides the following insights:

The Midwest region has a higher impact of price on consumption of electricity, with an elasticity value of -0.018 measuring the sensitivity of consumers when price increases. This means that on average an increase in price of 1% among consumers causes a decrease of 0.018% in electricity demand. The result in the Northwest is -0.038, characterizing inelastic demand in relation to price. This means that the variation in price does not have a meaningful influence on electricity consumption: a price increase of 1% reduces demand by 0.038%. The inverse occurs with an increase of income, although the result is also inelastic, but with a significant increase in demand with rising income in the region: a 1% increase in income raises demand by 0.916%. Since the region has many low-income people who do not have many appliances that need electricity to operate, when income rises, so does ownership of appliances, and consequently demand for electricity. Our income elasticity result for the Northeast is close to that of 0.876 obtained by Irffi and Catelar (2009) in the same region.

In the North, demand is also inelastic in relation to price, but the sensitivity is higher than found in the regions mentioned above. Here an increase of 1% in price causes a decline of 0.13% in demand. Income in this region, unlike in the others, is elastic, with a result greater than unity. Therefore, an increase of 1% in income leads to a rise of 1.05% in electricity demand. As in the Northeast, the North also has pent-up demand for electrical and electronic appliances, so higher income spurs the purchase of these devices and thus increases energy demand. Another characteristic of the region is that many households still do not have access to electricity, despite rural electrification initiatives such as the "Light for All" program, according to the Ministry of Mines and Energy.

TABLE III. ESTIMATIONS OF LONG-RUN ELASTICITIES IN REGIONS

Regions	D^i_t	Ki	P^i_t	Y^i_t	E^i_t	L^i_t
Midwest	1.00	-6.270	0.018	-0.704***	0.16***	-0.53***
			(-0.052)	(-0.022)	(-0.046)	(-0.121)
			[0.355]	[-31.201]	[3.435]	[-4.419]
						$D_t = 6.271 - 0.018\,P_t + 0.704\,Y_t - 0.160\,E_t + 0.538\,L_t$
Northwest	1.00	-5.464	0.038	-0.916***	0.216***	-0.72***
			(-0.071)	(-0.037)	(-0.055)	(-0.154)
			[0.539]	[-24.717]	[3.906]	[-4.704]
						$D_t = 5.464 - 0.038\,P_t + 0.916\,Y_t - 0.216\,E_t + 0.727\,L_t$
North	1.00	-1.512	0.134	-1.056***	0.334***	-1.32***
			(-0.122)	(-0.072)	(-0.083)	(-0.254)
			[1.100]	[-14.608]	[4.026]	[-5.202]
						$D_t = 1.512 - 0.134\,P_t + 1.056\,Y_t - 0.334\,E_t + 1.32\,L_t$
Southeast	1.00	-8.746	0.056	-0.393***	-0.044	-0.633**
			(-0.122)	(-0.053)	(-0.103)	(-0.271)
			[-0.460]	[-7.385]	[-0.430]	[-2.331]
						$D_t = 8.746 - 0.056\,P_t + 0.393\,Y_t + 0.044\,E_t + 0.633\,L_t$
South	1.00	-9.431	0.193**	-0.564***	-0.024	-0.279
			(-0.081)	(-0.037)	(-0.076)	(-0.219)
			[2.373]	[-15.182]	[-0.316]	[-1.272]
						$D_t = 9.431 - 0.193\,P_t + 0.564\,Y_t + 0.024\,E_t + 0.279\,L_t$

Note: The Table shows the estimates of the cointegration vector $\beta' = (K, 1, \alpha, \theta, \gamma, \delta)$. The values in parentheses represent the standard error and the values in brackets are the *t*-statistics $\beta' y_{t-1} = (K, 1, \alpha, \theta, \gamma, \delta) \cdot \left[1, D^i_t, P^i_t, Y^i_t, E^i_t, L^i_t\right]'$, for each region i.

In the Southeast, consumers are inelastic in relation to income. An increase of 1% in income causes demand to rise by 0.39%. This region is the richest in the country, with virtually universal connection to the power grid, so the use of appliances is commensurately greater, for which electricity is essential.

In the South, as in the other regions, the signs are in accordance with those found in the literature. Demand is inelastic with respect to price, because a rise of 1% in price causes demand to fall by 0.19%. In turn, the relation between demand and income is inelastic: an increase of 1% in income leads demand to rise by 0.56%.

IV. CONCLUSION

The aim of this paper is to estimate the long-run price and income elasticity of demand for residential electricity in Brazil for each of the country's five geographical regions.

The results found demonstrate that demand is inelastic to price, as found by studies in other countries, and that the region most sensitive to variations in price is the South. An increase of 1% in the cost of electricity causes consumers to reduce demand by 0.018% in the Midwest, 0.038% in the Northeast, 0.134% in the North, 0.056% in the Southeast and 0,193% in the South.

With respect to income elasticity, the results show that demand for electricity is elastic in the North and inelastic in the other regions. An increase of 1% in income causes increased electricity consumption of 0.7% in the Midwest, 0.91% in the Northeast, 1.05% in the North, 0.39% in the Southeast and 0.56% in the South. Therefore, demand for electricity is most sensitive to variations of income in the North and Northeast.

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Appendix

Unit root – Independent variable

Variable	ADF Test(2)	ADF ^{GLS} Test(3)	PP Test(4)	KPSS(5)
	t-Statistic	*t-Statistic*	*t-Statistic*	*t-Statistic*
$Rain_t$	-4.016442 ***	-3.992811 ***	-12.22565 ***	0.814225 ***
$\Delta Rain_t$	-6.398230 ***	-0.987295	-74.69276 ***	0.269713
$temp_t$	-5.567471 ***	-5.547623 ***	-5.521373 ***	0.588921 **
$\Delta temp_t$	-8.269978 ***	-8.300499 ***	-51.60773 ***	0.336098