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Article

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Provided in Cooperation with:
International Journal of Energy Economics and Policy (IJEEP)

Reference: Martins, Luís Oscar Silva/Fernandes, Fábio Matos et. al. (2023). Dynamics of industrial electricity demand in the State of Bahia (Brazil) : evolution of price and income and COVID-19 implications. In: International Journal of Energy Economics and Policy 13 (2), S. 1 - 8.
https://econjournals.com/index.php/ijeep/article/download/13979/7177/32573.
doi:10.32479/ijeep.13979.

This Version is available at:
http://hdl.handle.net/11159/630161

Kontakt/Contact
ZBW – Leibniz-Informationszentrum Wirtschaft/Leibniz Information Centre for Economics
Düsternbrooker Weg 120
24105 Kiel (Germany)
E-Mail: *rights[at]zbw.eu*
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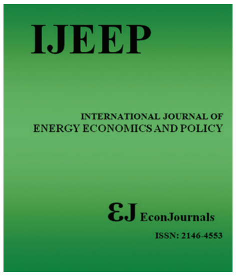

International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2023, 13(2), 1-8.

Dynamics of Industrial Electricity Demand in the State of Bahia (Brazil): Evolution of Price and Income and COVID-19 Implications

Luís Oscar Silva Martins[1]*, Fábio Matos Fernandes[2], Alex A. B. Santos[3], Euclides Santos Bittencourt[4], Marcelo Santana Silva[5]

[1]Universidade Federal do Recôncavo da Bahia, Brazil, [2]Universidade Federal da Bahia, Brazil, [3]Integrated Manufacturing and Technology Center, Senai, Cimatec, Brazil, [4]Federal Institute of Bahia, Brazil, [5]Federal Institute of Bahia, Campus Salvador, Brazil. *Email: luisoscar@ufrb.edu.br

Received: 11 November 2022 **Accepted:** 04 February 2023 **DOI:** https://doi.org/10.32479/ijeep.13979

ABSTRACT

The growth in demand for electricity is a determining factor for the regional development. This research aimed to estimate the price and income elasticity parameters of the industrial demand for electricity in the State of Bahia, Brazil, from January 2003 to June 2022, in addition to making forecasts for the period from July to December 2022. After verifying that some of the analyzed data were non-stationary, we chose to use the cointegration method, estimating the econometric model through the Error Correction Mechanism (ECM). The ECM considers the model's variables and their lags, relating the series' short and long-run trends. The estimated parameters were inelastic and presented the following values: 0.501 and 0.762 (price and income, long-run) and 0.482 and 0.702 (price and income, short-run). The adjustment coefficient between the short and long-run was also statistically significant and indicated that approximately 8% of the difference between the effective value and the long-run value (balance value) is corrected in each period, demonstrating the rigidity of the consumption structure of electricity in the industrial sector in Bahia. The model also demonstrated an 8.1% reduction in consumption during COVID-19 incidence period. Regarding the forecasts, they proved to be robust and with an average difference of 5.4% in relation to what actually happened in the months of July and August 2022. Thus, the calculated parameters are configured as another source of information for public policymakers and private investors interested in the electricity sector in the State of Bahia.

Keywords: Electricity, Electric Demand in Industrial Sector, Bahia, Brazil, Cointegration Relations
JEL Classifications: C1, C5, R1 and R2

1. INTRODUCTION

Electric energy is one of the main sources that make up the Brazilian energy matrix. It represents 18.7% of final energy consumption. In Brazil, the main source used is water, responsible for 56.8% of the domestic supply of electricity, with the industry having the second largest sectorial share (26.4%), behind only the residential sector (EPE, 2022a).

According to the National Confederation of Industry (CNI, 2021), the industrial sector represents 20.4% of the Gross Domestic Product (GDP), 69.2% of exports, 69% of private investment in research and development and, 33% of national tax collection. In addition, the sector generates approximately 10 million direct jobs.

Bahia is the fifth largest state in Brazil in terms of territory, the fourth most populous and, the seventh in economic importance[1] (IBGE, 2022a). Unlike Brazil, the main source of electricity generation is wind, representing 40.5% of the State's matrix. Bahia has 844 projects in operation, with approximately 30.654 MW of generation potential. Of these, 13.500 MW (44%) correspond to

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[1] Brazil has 26 states and a Federal District, where the country's capital, Brasília, is located (Authors' Note).

wind power plants (ANEEL, 2022a). The industrial sector is the largest consumer, responsible for 36.6% of consumption in 2021 (EPE,2022b).

Despite being important, both for public policy makers and private investors in the electricity sector, the modeling of industrial electricity demand has been little explored in the literature. Among the main studies for Brazil, converging with the theme proposed in this article, the following stand out: Mattos (2005), Modiano (1984), and Schmidt and Lima (2004). These industrial sectors together with residential and commercial sectors.

At regionalized levels, the research is even more sparse. Only Dantas et al., (2016), Dantas et al. (2017), Irffi et al. (2009), and Mattos and Lima (2005) studied industrial demand regionally.

International studies that individually address the industrial demand for electricity are also scarce. Wang and Mogi (2017) studied the dynamics of industrial electricity demand in Japan using annual data and a time-varying parameter with a Kalman filter. The authors noticed a structural break in electricity consumption in the sector after the deregulation of the Japanese electricity market. They also realized that the new pricing policy implemented, through the inclusion of an environmental tax, had little impact on the industrial sector.

Campbell (2018) estimated the price and income parameters of industrial, residential, and commercial demand in Jamaica. Using cointegration techniques with vector autoregressive modeling (VAR) and Vector Error Correlation Mechanism (ECM), the author showed that price is significant to explain the behavior of industrial electric demand. It showed also that industry and commercial consumers are more sensitive to changes in income than residential consumers.

Industrial energy demand was also modeled in Saudi Arabia (Alarenan et al., 2020). There, starting in 2016, pricing policies were established that increased the cost of energy inputs for the industry. These higher prices have reduced electricity consumption in the country.

In the United States, Pielow, Sioshansi, and Roberts (2012) estimated the short and long-run in price and income elasticities of the industrial and commercial sectors. They used autoregressive estimators and climate data for future estimates of electricity consumption. The short-run model used by the authors, based on climate data was able to make predictions with 95% reliability.

In this context, the present work differs from previous studies in three different ways. First, monthly data is used. Data with lower levels of aggregation can identify more pronounced differences in behavior in the variables and in the individual under study (Martins et al., 2021), offering more robust estimates of the parameter.

Second, it narrows the gap, both in the domestic and international literature, in the analysis of regional demand for electricity in the industrial sector. This type of analysis can be particularly useful for regional public policy managers and potential private sector investors. Third, according to bibliographical research, this study is one of the pioneers in assessing the impacts of COVID-19 on industrial electricity demand.

Thus, the main goal of this article is to estimate the price elasticity and income elasticity, in the short and long-run, of the industrial demand for electricity in the State of Bahia in the period from 2003 to 2022. Specifically, it verified the behavior of industrial electricity consumption in the period of incidence of COVID-19, and finally, it carried out estimates of the consumption of industrial electricity in the State of Bahia for the period from July to December 2022, making it possible to compare the results with what occurred until August 2022, verifying the quality of the estimator.

This article is structured in five sections besides this brief introduction. Section two presents the situation and characteristics of industrial electricity consumption in the State of Bahia. In section three is presented the econometric model and the data used. The fourth presents and discusses the results found. And finally, section five shows the research conclusions.

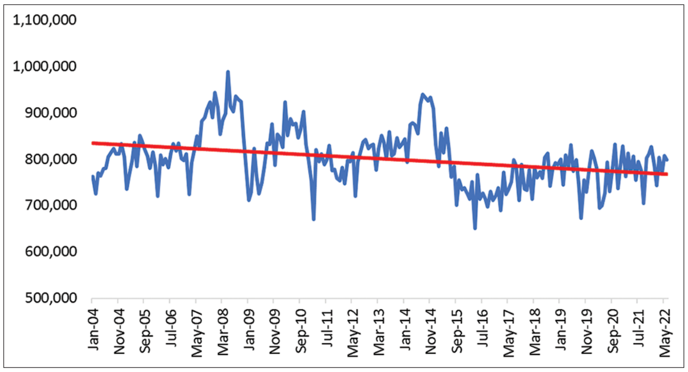
2. INDUSTRIAL CONSUMPTION OF ELECTRICITY IN THE STATE OF BAHIA

Electricity consumption in the industrial sector in Bahia has remained constant when analyzing the period from 2004 to 2022, as shown in Figure 1. In January 2004, consumption was 762.417 MWh, while in June 2022, it was 798.210, an increase of only 4.7% over the entire period (ANEEL, 2022b). The red line shows a slight downtrend.

Regressing a log-linear model of electricity consumption against time, we see this slight decrease in industrial energy consumption. It decreased by an average of 0.3% per year. Likewise, in the regression of a linear model of consumption against industrial GDP and time, the angular coefficient of the time variable showed a negative sign (0.043), confirming once again the trend of a slight decrease in electricity consumption in the industrial sector of Bahia.

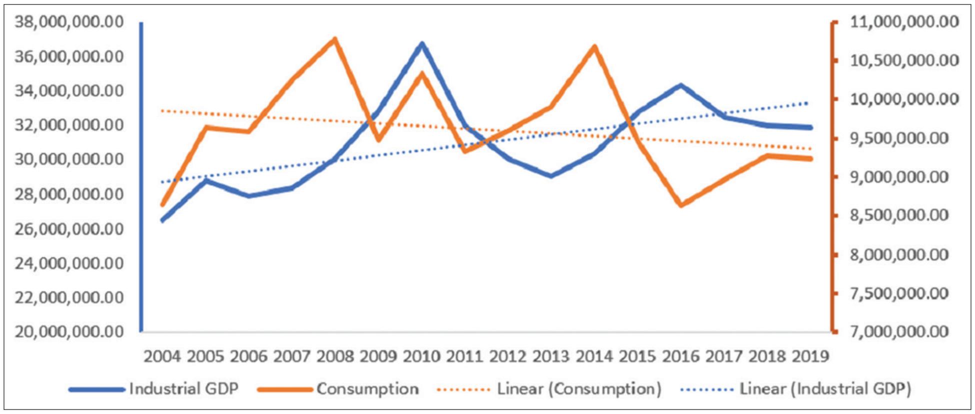
Comparing industrial GDP with electricity consumption, Figure 2 shows the dynamic and integrated behavior between the two

Figure 1: Electricity consumption in the industrial sector in the State of Bahia



Source: ANEEL (2022b)

Figure 2: Relationship between industrial GDP and electricity consumption



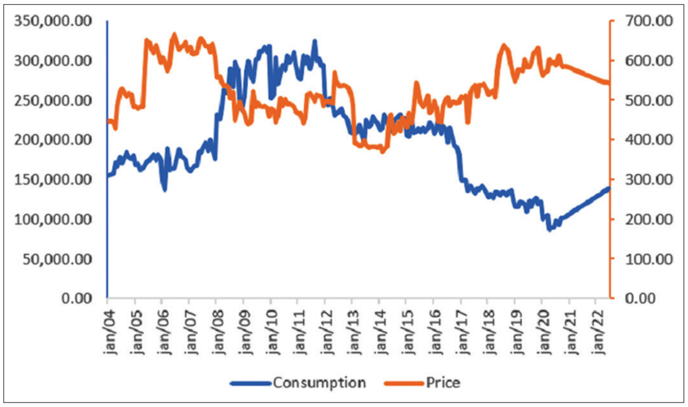
Source: IBGE (2022a) and ANEEL (2022b)

variables. The difference is due to the linear growth trend. While the GDP shows a growth trend, consumption tends to reduce over time. This result may be associated with the energy efficiency improvement process that the industry sector of Bahia has been going through in recent years (Marques et al., 2020; Mascarenhas et al., 2019).

Regarding price, the average tariff per MWh of the industrial sector, in constant June 2022 prices, deflated by the Extended Consumer Price Index (IPCA), increased by 21.5% in the period. While in January 2004, the amount was BRL 446.27, in June 2022, the amount was BRL 542.09[2]. The historical series (Figure 3) shows a drop in consumption since 2015, due to the economic and political crisis experienced by Brazil at that time (Barbosa Filho, 2017). Consumption shows a downward dynamic behavior since 2012, maintaining the trend until 2020. However, in the period from 2013 to 2017, there is a period of stabilization, influenced, at first, by the price drop, which was reestablished in 2015. This movement proved to be accentuated in 2020, due to the impact of COVID-19, but since the last quarter of 2020, a recovery process has started.

According to ANEEL (2022a), Bahia has 844 electricity-producing enterprises. The granted power of the system is approximately 30.654MW. In terms of installed capacity, the main generating sources are wind (EOL) (44%), followed by solar (UFV) (30.4%) and water (UHE, PCH and CGH) (18.7%). Table 1 shows the sources used, the power granted, and the percentage of participation of each source's contribution to the State's installed capacity.

Figure 3: Price of industrial electricity compared to consumption in MWh



Source: ANEEL (2022b)

Table 1: Electricity generation infrastructure in the State of Bahia, Brazil

Source	Power granted (MW)	Enterprises	%
EOL	13.500	447	44.04
UHE	5.613	10	18.31
UTE	2.102	112	6.86
UFV	9.332	252	30.44
PCH	107	8	0.35
CGH	0.135	19	0.0004
Total	30.654	848	

Source: ANEEL (2022). The percentage values refer to the share of each source in the State's installed capacity. UHE (Hydroelectric Power Plant); PCH (Small Hydroelectric Plant); CGH (Hydroelectric Power Plants); UTE (Thermoelectric Generating Center); EOL (Wind Generating Center); UFV (Photovoltaic Generator Center)

According to Table 1, we see a big difference in the profile of electricity generation between the State of Bahia and Brazil. Regarding to country**,** the main source is hydro, which corresponds to 56.8% of the domestic supply of electricity (EPE, 2022a), while in the State the most used source is wind, followed by photovoltaic. Bahia has evolved in recent years in the use of renewable sources. The presence of strong and consistent winds along the coast of the region, as well as the convergence of subtropical anticyclone winds from the South Atlantic and the trade winds from the East, favored the use of wind energy (de Jong et al., 2017). Regarding photovoltaic energy, several regions of Bahia, such as the West and North regions, have a high incidence of Global Horizontal Irradiation (GHI), with an incidence of solar irradiation above 2,000 kWh/km^2, highlighting the State's solar potential (INPE, 2017; SECTI et al., 2018).

This difference in the State's matrix, in relation to the country, can be considered as a competitive advantage, since wind and solar

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[2] In dollars, the values would be U$ 85.53 in January 2004 and U$ 105.06 in June 2022. Exchange rate of the dollar against the Brazilian real on June 20, 2022 (BCB, 2022).

sources do not depend on the rainfall regime, making the supply constant and less unstable.

3. METHODOLOGY AND DATA

3.1. Short and long-run model for estimating the demand function

We estimated the industrial demand for electricity in Bahia, through a *Cobb-Douglas* type function, with monthly data from January 2003 to June 2022, totaling 234 observations. According to Mattos (2005) and Mattos and Lima (2005), one of the main features of this functional form is that the elasticity values are constant and equal to the parameters of variables in their logarithmic form. The function was specified according to Equation 1:

$$c_t = k.p_t^{\beta_1}.ip_t^{\beta_2}.gp_t^{\beta_3}.ipa_t^{\beta_4}.\gamma_t.\mu^{\varepsilon_t} \tag{1}$$

Deriving the function and taking its logarithmic form, we find the linear function, described according to Equation 2:

$$lnc_t = \alpha + \beta_1 lnp_t + \beta_2 lnip_t + \beta_3 lngp_t + \beta_4 lnipa_t + \gamma_t + \varphi + \varepsilon_t \tag{2}$$

where, lnc_t, is the natural logarithm of industrial electricity consumption over time, α is the intercept of the demand function, lnp_t é is the logarithm of industrial electricity price over time,, is the logarithm of industrial production over time, $lngp_t$, is the neperian logarithm of the price of industrial natural gas and $lnipa_t$ is the logarithm of the price index related to industrial goods. γ_t is a dummy variable to capture the periods of incidence or not of COVID-19 and ϕ represents the temporal trend. The β, represent the parameters of the respective variables.

The use of the average price of electricity as a proxy may have implications for estimating the demand function. Since there is a bilateral dependency between the average price and the amount of electricity consumed, the model has two endogenous variables, one of which is a regressor. Thus, it is likely that there is a simultaneity bias between the variables, making the use of the Ordinary Least Squares (OLS) method impractical.

According to Alberini and Filippini (2011), two methodologies can be used in this case. The first is simultaneous equation models, and the second is cointegration techniques. For this work, after performing the stationary and cointegration tests, we chose to use the second model. The main advantage of the ECM is that it allows the use of level variables, without losing the long-run relationship between them, thus correcting possible short-run imbalances (Wooldridge, 2012).

Cointegration techniques follow the model adopted by Johansen (Johansen, 1991). This methodology proposes an autoregressive model (VAR) to estimate cointegration vectors. For future estimation of electricity consumption in the industrial sector, the VAR was represented according to Engle and Granger (1987), in the form of an ECM. The VAR/ECM modeling is better suitable for this research because it takes into account all the variables and their lags, reconciling the model's short- and long-run trends.

Before the cointegration analysis, the stationary of the series was checked. For this, we used the Augmented Dickey-Fuller (ADF) unit root and Phillips-Perron (PP) test. After identifying the problem, the ECM was used and is represented by Equation 3:

$$\begin{aligned} \Delta lnc_t &= \alpha + \beta_1 \Delta lnp_t + \beta_2 \Delta lnip_t + \beta_3 \Delta lngp_t + \\ &\beta_4 \Delta lnipa_t + \gamma_t + \varphi + \delta\varepsilon_{t-1} + \omega \end{aligned} \tag{3}$$

where the Δ represents the first difference of the series. The ε_{t-1}, represents the empirical estimate of the error term in the equilibrium, which captures the equilibrium adjustment estimate in the long-run. Parameter δ is the adjustment coefficient. If significant, it shows the proportion of imbalance in the dependent variable, which is corrected in the subsequent period. ω is the general random error term of the model.

Thus, Equation 2 represents the long-run relationships between electricity consumption and its determinants, while Equation 3 is the ECM used, which illustrates the short-run relationships between electricity consumption and the regressors, as well as the model imbalance percentage that is adjusted each period.

From the VAR, the Error Correction Model (ECM) was estimated. According to Engle and Granger (1987), each cointegrated series has a representation of an ECM, with some adjustment process between the short and long-run. Respecting the assumptions of an absence of serial correlation and the presence of normal distribution, it is possible from ECM to make future estimates of electricity consumption in the industrial sector.

3.2. Data

Industrial electricity consumption (captive consumption) was collected from the National Electric Energy Agency (ANEEL, 2022b). Free consumption was collected from the statistical yearbook of electricity, produced by the Energy Research Company (EPE, 2022b). The sum of both, free and captive consumption, resulted in the total electricity consumption of the industrial sector in Bahia.

The price was also collected from ANEEL (2022b). The economic theory, in the study of the demand for electricity, diverges on the *proxy* used about the price. There are studies that support the use of marginal price (Alberini et al., 2011; Reiss and White, 2005), and studies that support the use of average price (Irffi et al., 2009; Martins et al., 2021; Uhr et al., 2019). The problem is that marginal prices are not available in Brazil, so studies developed on industrial demand use average prices (Dantas et al., 2016; Gross et al., 2017; Mattos et al., 2005). However, older works (Parks and Weitzel, 1984), as well as contemporary studies (Cialani and Mortazavi, 2018; Huntington et al., 2019), argue that industrial consumers respond better to the average prices. Therefore, the average price as a *proxy* was used in this research.

For income, industrial production (*ip*), from the Monthly Industrial Survey (PIM) from the Brazilian Institute of Geography and

Statistics (IBGE, 2022b) was used. The *ip* reveals the behavior of the industrial physical production of each state of Brazil, better and more dynamically reflecting the performance of the industry.

The price of industrial natural gas *(gp)* was obtained from Bahia' Gas Company (BAHIAGAS, 2022). The broad price index related to industrial goods was collected from the Institute of Applied Economic Research (IPEA, 2022). All series are in constant values of June 2022, updated by the Extended National Consumer Price Index (IPCA) of IBGE (2022c). Table 2 shows the descriptive statistics of variables used in the analysis.

4. RESULTS AND DISCUSSION

First, the results of the estimation of short and long-run models of industrial electricity consumption for the state of Bahia were presented. Then, consumption forecasts were considered, using the vector correction model for pre-defined periods.

4.1. Demand Function Estimation

The results of the unit root test (ADF), for the analyzed series, are shown in Table 3.

To select the number of lags, we followed the criteria established by Schmidt and Lima (2004). According to the authors, initially a high number of lags is defined (six, for example). Later, it is verified whether the lag is statistically significant. If so, the series now have *n* lags. Otherwise, the test is repeated with *n-1* lags. Once the number of lags has been found, the constant and trend are included. If the trend is significant, the equation has a constant and trend.

For the analysis in question, according to Table 1, the constants were significant. Table 3 also shows that for *Δlnc, Δlngp e Δlnipa*, it is impossible to reject the null hypothesis of the presence of a unit root, that is, the series are non-stationary. As for *Δlnp* e *Δlnip*, the null hypothesis is rejected, at the 1% level of significance, and it can be stated that the series are stationary.

Since some of the analyzed series were non-stationary, we performed the unit root test in the first difference. The test results are shown in Table 4.

Table 4 shows that all differing series are stationary at the 1% significance level. Therefore, the null hypothesis of the presence of a unit root in the series in difference is rejected, concluding that they have the same order of integration I(1), being possible the existence of an integration relation between the series.

We checked the cointegration between the series using the Engle-Granger test (Engle and Granger, 1987). The test uses a VAR to verify the long-run cointegration relationship between series. Regarding the number of lags, we used the Akaike criterion (AIC)[3]. The criterion indicated that VAR should include three lags in each of its variables. The cointegration test verified that the residual ε_t is stationary at the 5% significance level. The series, therefore, are cointegrated in the same order [I(1)] and the residuals are integrated in the zero order I(0). The result of the Engle-Granger can be seen in Table 5.

Table 5, using the Engle-Granger test, demonstrates that there is a long-run relationship between the variables in the series. Thus, this relationship can be represented according to Equation 5:

$$\begin{aligned} \ln c_t = {} & 2.821 - 0.501 \ln p_t + 0.762 \ln ip_t - 1.484 \ln gp_t \\ & (0.0461)\,(0.098) \qquad (0.146) \qquad (0221) \\ & +0.856 \ln ipa_t - 0.267\,\mathrm{cov} - 0.011\varphi \\ & (0.413) \qquad (0.117) \qquad (0.0001) \end{aligned} \tag{5}$$

where the values in parentheses are the standard deviations of the estimated parameters. The statistics calculated for all parameters are statistically significant at the 5% level and the signs are in accordance with economic theory. The exception was the sign of the price readjustment index for the industrial sector, which was positive.

According to Equation 5, a 1% increase in electricity price would lead to a 0.5% reduction in consumption, while a 1% increase in

Table 2: Descriptive statistics of the variables used in the analysis

Variables	Obs.	Mean	SD	Min.	Max.
c	234	193,084.3	61,075.78	87,332.41	324,677
p	234	519.77	72.71	353.99	665.10
ip	234	92.66	10.34	59.056	115.27
gp	234	2.195	0.24	1.75	2.98
ipa	234	515.53	210.87	261.97	1,183.047

Table 3: Unit root tests (ADF)

Variable	Terms	Lags	ADF	Critical values	
				1%	5%
Δlnc_t	Constant and trend	3	−0.979	−3.467	−2.881
Δlnp_t	Constant and trend	3	−3.214	−3.467	−2.881
$\Delta lnip_t$	Constant and trend	3	−3.632	−3.467	−2.881
$\Delta lngp_t$	Constant and trend	3	−0.451	−3.467	−2.881
$\Delta lnipa_t$	Constant and trend	3	1.436	−3.467	−2.881

Table 4: Unit root tests (ADF), in series in first difference

Variables	Terms	Lags	ADF	Critical values	
				1%	5%
Δlnc_t	Constant and trend	3	−7.994	−3.997	−3.433
Δlnp_t	Constant and trend	3	−8.499	−3.997	−3.433
$\Delta lnip_t$	Constant and trend	3	−9.802	−3.997	−3.433
$\Delta lngp_t$	Constant and trend	3	−8.252	−3.997	−3.433
$\Delta lnipa_t$	Constant and trend	3	−5.802	−3.997	−3.433

Table 5: Engle-Granger cointegration test performed for the series of interest in the period from 2003 to 2022

Error	Terms	Lags	Test statistics	Critical value of 5%
ε_t	No trend and no intercept	0	−3.052	−1.950

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[3] AIC information criterion measures the quality of a statistical model by observing its simplicity. It is a metric for comparing and selecting models, in which lower AIC values represent greater quality and simplicity of the model.

income would lead to a 0.76% increase in electricity consumption, over the long-run. The parameter that measured the impact of COVID-19 was also significant. According to Equation 5, during the analyzed period, consumption decreased by an average of 26.7%. Most of the decrease in electricity consumption occurred, especially, between the years 2019 and 2020 (26%). Between 2020 and 2021, there was an increase in consumption (compared to the previous year) of 10%.

As shown in the methodological section, the series are possibly integrated and represent a long-run relationship for industrial electricity consumption in the State of Bahia. Thus, the short-run relationship was estimated, as well as the ECM of the model. The results are shown in Table 6.

ECM represents the short-run adjustment of the dependent variable (industrial electricity consumption) and other model variables. The estimated values make it possible to describe the short-run relationship between the regressors through Equation (6):

$$\Delta lnc_t = -0.009 - 0.482\Delta lnp_t + 0.702\Delta lnip_t - 1.328\Delta lngp_t + 0.265\Delta lnipa_t - 0.081cov_t - 0.0805\varphi - 0.0805\varepsilon_{t-1} + \lambda_t \qquad (6)$$

That is, a positive variation in price by 1% would reduce industrial electricity consumption by 0.482%. Regarding industrial production, when it increases by 1%, consumption changes by 0.702% in the same direction. The short-run price elasticity was estimated at -.A% in the same direction. In the short-run, we found that the parameter representing the incidence of COVID-19 continues to be negative. That is, the incidence of COVID-19 reduced electricity consumption in the short-run by 8.1%. The lower value of the parameter (in relation to the long-run), can be explained by the fact that after a period of retraction in the industry, economic activity recovered again. The Federation of Industries of the State of Bahia (FIEB, 2022) showed that Bahia' industry grew by 26%, comparing the first half of 2022 with that of 2021.

The estimated adjustment coefficient (ECM) was significant at 1%, showing the proportion of short-run imbalance in the industrial demand for electricity in the State of Bahia that is corrected from the following period. The estimated value was 0.0805, indicating that 8% of the difference between the effective value and the long-run value (equilibrium value) is corrected at each period. Hence, according to the analysis, the industrial sector in Bahia would take approximately a little over 12 months to adjust the quantity of electricity demanded to possible external shock in prices and/or industrial production.

Testing the normality of the residues, through the Shapiro-Wilk test, the results showed that at 5% of significance, the residues behaved according to normal distribution. The test statistic was 0.545. The *Portmanteau* test statistic to check whether the residuals are a random walk was 0.232, indicating that the random perturbation is a white residue[4].

After confirming the cointegration relationships of the variables, as well as the prerequisites related to the normality of the residues and the absence of serial correlation, forecasts of electricity consumption in the industrial sector in Bahia were developed. The results are presented in section 4.2 below.

4.2. Forecast of Industrial Electricity Consumption in the State of Bahia

In this section, forecasts of electricity consumption in the industrial sector in the state of Bahia were made. Estimates were calculated for the months of July to December 2022. At the time of writing this article, consumption information already existed for the months of July and August. So, the values found were compared with reality, which demonstrated the robustness of the estimators used, allowing forecasts for the months of September to December 2022. According to the proposed methodology, we made forecasts through techniques and cointegration to from a VAR, in the form of an ECM model.

4.2.1. Estimate through VAR

To make the forecasts for electricity consumption in the industrial sector of the State of Bahia, the ECM was estimated by VAR, which was used for the cointegration test of Johansen model (Eq. 6). As the variables are cointegrated, there is an adjustment process between the short and long-run. The ECM, thus, provides the speed of adjustment between short-run deviations from the long-run trend (Engle and Granger, 1987).

Table 7 shows the results of the estimates for the months of July to December 2022. In addition to these results, the table shows the observed and predicted values until August 2022 (data available at the time of writing this article) and the differences in values and in percentages.

Table 7 shows that the difference between the observed and predicted values for July and August 2022 are 7.9% and 2.9%,

Table 6: ECM estimation of the industrial demand for electricity in the State of Bahia (2003-2022)

Variable	Regressor	Standard deviation	Statistic *t*
Δlnp_t	−0.482***	0.022	−21.4
$\Delta lnip_t$	0.702***	0.016	42.85
$\Delta lngp_t$	−1.328***	0.072	−18.37
$\Delta lnipa_t$	0.265***	0.121	14.41
cov	−0.081***	0.004	−1.75
ϕ	−0.008***	0.0001	−0.40
$\delta\varepsilon_{t-1}$	−0.0805***	0.303	26.57
Constant	−0.009***	0.002	−3.52

Table 7: Electricity consumption forecasts for the industrial sector for the period from July to December 2022

Period	Observed value MWh	Predicted value MWh	Difference	Difference %
July/2022	836,703	903,130	66,424	7.9%
August/2022	820,223	844,750	24,527	2.9%
September/2022	-	777,978	-	-
October/2022	-	763,802	-	-
November/2022	-	759,286	-	-
December/2022	-	738,584	-	-

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[4] This is to verify the presence of a serial correlation. The null hypothesis of the test is that there is a serial correlation. Therefore, if the value of p is greater than 0.05, the null hypothesis of the test is rejected.

respectively. These values are consistent with previous studies, such as Schmidt and Lima (2004), which found an average annual difference of 5.3% between predicted values and observed values. Gross et al. (2017) made forecasts for electricity consumption in Brazil, finding an average monthly difference of 2.6%.

From the results obtained, we can say that the model used is consistent for making short-run forecasts of electricity consumption in the industrial sector in the state of Bahia. Despite the monthly database, in which oscillations are more pronounced and less predictable, the model proved to be consistent, following the downward trend observed in consumption.

5. CONCLUSIONS

This study sought to contribute to the literature on estimating elasticities, specifically price and income, of electricity demand in the industrial sector, from a regional perspective, particularly, the parameters for the state of Bahia, Brazil.

To do this, we used variables that were consistent with previous studies but related with the state of Bahia. The study showed that the consumption of electricity in the industrial sector of the region has been decreasing, on average, by 0.3% per year. It also showed a sharp reduction of 26% during the period of COVID-19.

The calculated short-run and long-run price elasticities were 0.482 and 0.501, respectively. The income elasticities, for the same periods, were 0.702 and 0.762. The values found are in agreement with the literature and economic theory. That is, it confirmed the hypothesis that electricity is a normal good. In both cases (short and long-run) the behavior of the parameters was inelastic.

The research also estimated the adjustment coefficient for possible internal shocks to industrial consumption. The parameter value was 0.0805, indicating a slow rate of adjustment (8%) in each period. This indicates that long-run imbalances are slowly corrected, showing the rigidity of the sector's structure.

Natural gas proved to be a complementary good to electricity, with calculated values of −1.328 and −1.484 (short and long-run). The parameters proved to be elastic to consumption and reflect the reality of the market, considering the volume of industrial natural gas distribution in the State (3.6–4 million m^3/day) and the competitiveness of the price of the input.

In addition to the elasticity parameters, this survey also carried out short-run forecasts for the consumption of electricity in the industrial sector, based on the estimated ECM. Values were consistent since the differences between the observed values and estimated values (July and August 2022) were small, 7.9% and 2.9%, respectively, indicating the robustness of the estimator. The forecasts also showed the downward trend captured by the model.

As a future research agenda, it is proposed to estimate and forecast the parameters through other estimators, such as the Box-Jenkins model, in order to compare with the official estimates of EPE and ANEEL. It is also suggested that this study be expanded to other states and regions of Brazil, which would enrich the literature on the subject and serve as a further source of information for public policymakers and potential private investors interested in the electricity sector.

6. ACKNOWLEDGMENT

To the Federal Institute of Education, Science and Technology of Bahia (IFBA), campus Salvador, through Notice No. 18/2021/DPGI/DIREC/IFBA-Campus Salvador. PRPGI-IFBA: Pró-Reitoria de Pesquisa de Inovação do Instituto Federal da Bahia. CNPq: Conselho Nacional de Desenvolvimento Científico e Tecnológico.

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