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Economic tariff signal as a tool for the efficiency of electric energy distributors: a case study

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ABSTRACT

This article tests the hypotheses of consumers' response due to a change in the hourly economic rates given through electrical energy tariffs. In this study was analyzed the effects on the use of electrical energy of 218 consumers of an electric utility company in Rio Grande do Sul, due to the amendment occurred in the economic signal since April/2013 and based on peak load pricing theory. The effects were examined and tested by using their data from January/2012 to May/2016. The experience of this case corroborates with the hypotheses of this theory, which indicates that prices must be linked to supply marginal cost, which is bigger at peak hours. The presented hypotheses was tested by using the differences in differences econometric method, which results turned to be robust when showing that a change in economic signal strongly influences on consumers behaviors, improving the usage of electrical assets.

Keywords: Economics of Regulation; Hourly Economic Signal; Tariff structure; Differences in differences; Insider Econometrics.

JEL: D22; L51; L94.

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INTRODUCTION

The article aims to evaluate whether the economic hourly signal, given through electric energy tariffs, affects the behavior of consumers and, as a consequence, the use of distribution assets of the electric utility company. The analysis was performed on a specific electric utility in the state of Rio Grande do Sul from January/2012 to May/2016 with a group of 218 industrial consumers.

The economy and economic agents react to incentives, so excessively high electricity tariffs encourage consumers to seek other sources of energy, such as diesel oil. The behavior of the consumption of electric energy varies throughout the day, and depends on the habits of the consumers, income among others. The great diversity of consumers means that the use of assets has its most used capacity at certain times and less used in others, what is conventionally called peak load time and off-peak load times.

According to Boiteux (1960), pricing should be based on the cost of servicing an additional unit of demand, or on a marginal cost. In the case where the aggregated demand is constant in time, the price can be stable and unique. On the other hand, in the supply of products and services with variable demand, the problem of peak prices arises. The author also says as the installed capacity for electricity distribution is fixed in the short term, the most appropriate way to define the tariff structure is to encourage consumers to consume energy, so that, the daily format of the total consumption curve is horizontal, that is, without valleys, which means idleness of installed capacity. For Bergstrom & Mackie-Mason (1991), using differentiated tariffs throughout the day it is possible to use the installed capacity more efficiently, optimizing the use of the assets.

Viscusi et al. (2001), presents that marginal cost is higher at times of higher demand, so prices should be higher at these times. Thus, a possible solution is to price at the short-run marginal cost in off-peak demand periods and long-run marginal cost (expansion of installed capacity) at peak load time demand. The hourly price differentiation on the basis of marginal cost is an efficient way to define prices in the peak period.

Munasinghe (1981) shows that, in order to promote better utilization of installed capacity and avoid unnecessary investments to meet peak demand, the marginal cost allows defining a price structure that varies according to the marginal cost of supply based on the kind of consumers, seasons, time of day, stress levels and based on geographic areas. Therefore, the price presents to the consumer the cost of the availability of the service at that moment. If the price is differentiated by period, the consumers will be induced to change their consumption to other periods when the cost of service is lower.

As reported by Tremolet (2009) there is a general agreement that tariff structure is important for economic efficiency. Besides that, according to Ramos, Brandao and Castro (2012) the tariff structure affects electric energy distributors in a different way and therefore, in addition to its study being fundamental, the results may be different in each electric utility company. In this sense, this work brings data and performs a rigorous econometric analysis, using an insider econometrics approach on a specific case, whose results are applicable only to the studied electric utility company. However, the theory and method of analysis are generalizable for other companies in the electricity distribution field as well as infrastructure companies. Thus, this work reinforces the importance of the construction of tariff structures based on a careful empirical analysis, which emphasizes the consequences on the allocative efficiency of the assets.

In the analyzed case, the change in the tariff signal was due to the tariff reduction in the on-peak time rate, which does not coincide with the real peak load period; so that the price signal induces an increase in consumption of electricity in the period of the day when the assets are idle. The billing on-peak time consumption refers to the energy consumption between 6pm to 9pm and the billing off-peak time consumption between 9pm to 6pm.

In order to test whether the effect on the change of the economic signal produces changes in the form of the use of electric energy in a group of industrial and commercial consumers, the data were divided into two periods of time and two types of consumption. The first period refers to the months prior to April 2013 that is before the reduction of the tariff at on-peak time rate. The second period refers to the months from April 2013 that is post-change in the tariff signal. The question to be evaluated is: was the electricity consumption of these consumers at on-peak times altered by the reduction in the tariff signal that occurred in April 2013? If so, how much was that? What are the implications for these changes?

The methodology used in the analysis was the model of differences in differences, since it is possible to form a control group and a treatment group with data availability before and after the occurrence of the event. There are two kinds of consumption (on-peak time rate and off-peak time rate) and two time periods (before April 2013 and post-April 2013). The results show that consumption during the on-peak time rate after the tariff reduction increased 81.01% and without the need to expand the volume of investment, only via the incentive system generated by the tariff signal. This case reveals the importance of in-depth studies of the companies in order to define the economic tariff signs adhering to the hourly cost as a way of improving the allocative efficiency of the resources and consequently the profitability of the companies.

This study adopts the insider econometrics approach in which it uses primary data on a company's tariff policy so that, it can measure and evaluate the effects and implications of such change on consumer behavior, asset use, profit of the company, increased efficiency and improve the allocation of assets. It is believed that this is the first research that uses such approach in Brazil, in the field of electric energy.

In addition to this introduction, the article is structured in six more sections. In section two we present the theory of the economic signal in energy tariffs and peak prices based on marginal cost. After that, section three provides the description of the case and the database used and in the sequence, the section four shows the used methodology. The fifth stand out the results found in this research. Finally, in the sixth, the final considerations are presented.

ECONOMIC TARIFF SIGNAL

Electricity tariffs in Brazil are mean to be calculated on the basis of marginal cost theory. In this way, a tariff structure is created in which each consumer pays the equivalent of the cost of the provided service as well as increases the allocative efficiency of the economic system. According to the Brazilian regulatory model, tariffs are defined by voltage level[1], time period tariff[2] and are published through resolutions approved by the Brazilian regulatory agency that is the National Electric Energy Agency (ANEEL).

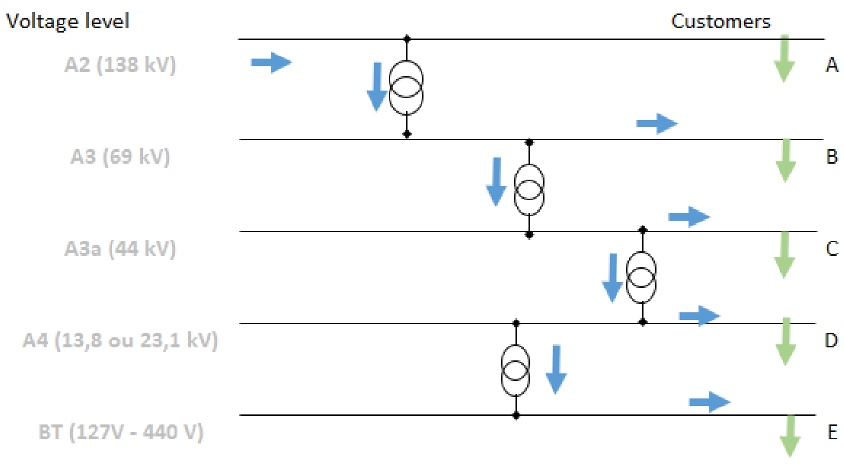
Electricity distribution grids are accessed by several kinds of consumers at different levels of connection (voltage levels). Thus, the prices are defined on the basis of the level of connection (vertical price structure) and how consumers use it (horizontal price structure). The figure below shows the customer service voltage levels as well as the traditional energy flow[3]:

Figure 1- Consumers Service Levels

[1] Corresponds to the voltage (in volts) that the consumer is connected to the distribution grid. For example, residential consumers, for the most part, are connected at 110v or 220v.

[2] Time period tariff refers to the time of day. Usually, the consumption between 6pm and 9pm corresponds to the consumption of time period tariff at on-peak time, and the complementary hours to this period refers to the time period tariff at off-peak time.

[3] For the purpose of this article, distributed generation is not needed to be represented along with another grid elements.



Source: Personal creation.

Figure 1 shows the energy flow and customer service (A, B, C, D and E). Customer "A", for example, receives the energy that enters the service level "A2", since it is serviced at the "A2" level. Consumer "B" receives the energy that enter in the level "A2", flows to level "A3", where this consumer is connected. Therefore, it is using assets at the "A2" and "A3" levels. Consumer "E" is served at the lowest level and because of that, it uses assets at all service levels. Therefore, it can be stated that customer service cost "A" is less than "B" which is less than "E".

$$\text{Cost A} < \text{Cost B} < \text{Cost C} < \text{Cost D} < \text{Cost E}$$

Thus, it is economically efficient for the consumer "E" pay a higher price than the consumer "D" who must be subjected to a price greater than "C" and so on.

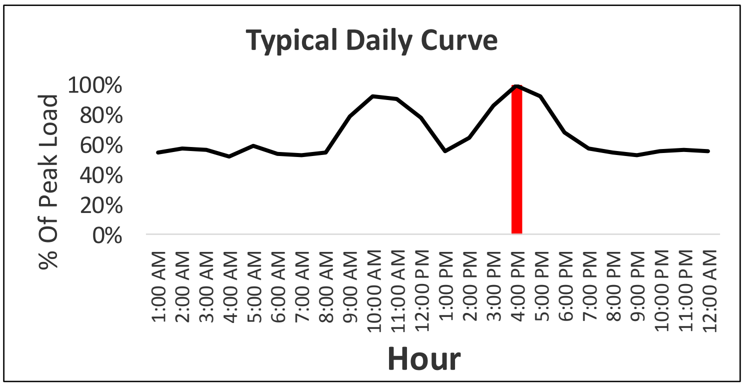
$$\text{Price A} < \text{Price B} < \text{Price C} < \text{Price D} < \text{Price E}$$

This price structure, in the Brazilian electric sector, is called the vertical price structure. Throughout the day, there are times of greater demand. By the characteristic of the electricity distribution service, the grids must be sized to meet the maximum load, otherwise the network would collapse. This means that at all other times, other than the maximum load, the grids operate with operational slack (DNAEE, 1985).

In terms of the marginal cost of expansion of the grid in order to meet the additional consumption, in the maximum load time the cost is higher, as the consequence is to expand the installed capacity, while at other times, it would still be possible to admit some additional load without the need for grid expansion. Based on this time cost it is defined the horizontal price structure.

Typically, electricity grids are subjected to some pattern of seasonality, daily, weekly or monthly. Consider the typical daily charge curve of a distribution grid based on Figure 2 below (DNAEE, 1985).

Figure 2- Typical Daily Curve of a Distribution Grid



Source: Personal creation.

Figure 2 presents that the maximum demand occurs at 16h, as indicated by the vertical bar, and at other times the demand for the grid is only a fraction of the maximum capacity, standing around 50% in the period, between midnight and 8am and the same from 8pm to the end of the day. Based on Figure 2 it is possible to assert that (i) the maximum tariff must be allocated at 4pm. Any different economic signals will encourage the consumer to shift the consumption to a time when, at worst, the grid is facing the maximum load. This movement implies the expansion of the grid without real need, only by an allocative price failure; (ii) consumers should be encouraged to shift their consumption to times when the rid is idle; (iii) consumers should be encouraged to increase their consumption out of the peak load times, which increases the company's revenue with the same amount of assets. The best way to use the grid, from the point of view of maximum utilization, occurs when the curve becomes a horizontal line, that is, the grid is always demanded for its maximum capacity which reduces grid idleness.

Peak price theory provides a solution for marginal cost pricing. According to Netz (1999) and Crew et al. (1995) this pricing is an appropriate regulatory mechanism when the good offered can not be stored, but is limited to the choice of a supply capacity. Defining prices is a cost allocation problem. The great prices depend on how much the cost of capacity is allocated in each time period.

As reported by Netz (1999), being a time period divided into T parts, during each t period, X_t units are produces. If K is the cost of capacity, that is, it is the common cost of production in all periods. The production function can be written by Yt = f (Xt, K). The cost of the variable of input is b, the cost of the variable of capacity is β. Assuming that the company operates under a regulatory regime in which it must meet the demand at all periods, and that the company focus its capacity to meet the maximum demand (y_t maximum), the cost function is given by:

$$TC_t = b * \sum_{t=1}^{N} y_t + \beta * \max(y_t) \qquad \text{(Equation 1)}$$

The total cost (TC_t) is equal to the cost of the input (b) multiplied by the quantity produced, plus the cost of capacity at the moment of maximum demand [max (y_t)]. For all periods that are not of maximum demand, the marginal cost is given by $\frac{dTC}{dy_t} = b$, because the second term of the equation is equal to zero. On other hand, the peak price, the derivative of the total cost becomes equal to a $\frac{dTC}{dy_t} = b + \beta$.

The described situation is similar to that found in the case study mentioned in this study, which will be analyzed in the next section.

THE CASE STUDY

The assets of the utilities are like machines of any industry, the longer the usage time is close to the nominal capacity of the equipment, the higher the gains will be. In other words, more services will be offered with the same installed capacity. When there is idleness in the production system, there is an investment that is not being remunerated.

The maximum demand of the distribution system, for which it must be dimensioned, depends on the coincident behavior of the consumers. By coincident behavior is meant the sum of the individual demand at each moment. If the maximum demands of the customers occur at the same time, the maximum demand of the system would be the sum of the maximum individual demands, but this situation is very specific and does not happen in practice. The maximum demand of the system is given by the sum of the individual demands, at the moment that the individual sum of the demands results in the maximum value, and these individual demands may or may not be the maxims for the specific individual.

A real distribution system has hundreds of service grids or feeders that provide power to thousands of consumers. For this work, grids of interest are those that serve consumers who substitute their energy at on-peak time tariff[4] for another energy source due to high tariffs, reducing the rational use of electric assets. Therefore, the focus is the influence of the economic signal, given through the energy tariff in the consumption habits of a specific class of consumers, and how it influences the company's revenue and the conditions of use of the assets.

Consumers of interest in this article can opt for two kinds of tariffs, depending on their level of service. The tariff options are called tariff modalities. The blue modality is characterized by four different prices: (i) demand[5] tariff at on-peak time[6]; (ii) demand tariff at off-peak time; (iii) energy tariff at on-peak time and; (iv) energy tariff at off-peak time. The green modality has three different prices: (i) single demand tariff; (ii) energy tariff at on-peak time and; (iii) energy tariff at off-peak time.

The on-peak time, which reflect the higher cost of expansion of this period, are higher than off-peak time tariff. Table 1 illustrates the current tariffs for consumers before the readjustment of the given tariff signal, evidencing the hourly component of tariffs.

Table 1 – Current Tariff before the readjustment

Tariff Modality	**Demand Tariff (R$/KWh)**		**Energy tariff (R$/MWh)**		**Relation on-peak time /Off-peak time**	
	On-peak time	**Off-peak time**	**On-peak time**	**Off-peak time**		
	18h-21h	21h-18h	18h-21h	21h-18h	Demand	Energy
Blue	51,33	18,56	354,56	211,11	2,77	1,68
Green	12,25		1.5446,53	211,11	NA	7,33

Source: National Electric Energy Agency - ANEEL

In the blue modality the economic signal of the demand is 2,77 and in the energy is 1,68. In the green modality, the economic signal is 7,33, that is, the tariff at on-peak time rate is 7,33 times higher than the at off-peak time rate. It means that, by observing the signal, the cost of expansion at on-peak time rate must be 7,33 times higher than the cost of expansion at off-peak time rate.

[4] It is emphasized that the term on-peak time refers to the period of the day when tariffs are higher. This time is different from peak load time, because this last one varies from utility to utility, and can occur at any time, including off-peak time tariff.

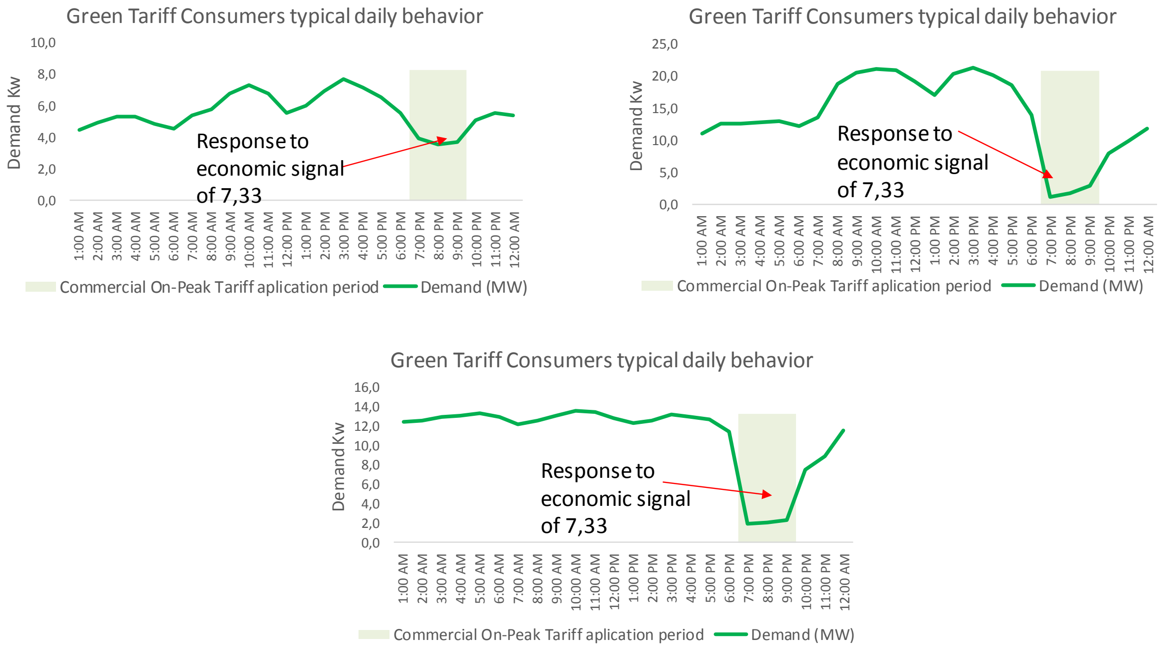
[5] It can be said that the demand is equal to the instantaneous energy consumed. Under the rules of the regulator, the billed demand is equals to the maximum measure.

[6] When the reference is the applied tariffs, the terms "on-peak time" and "off-peak time" are used, and in order to refer to periods of the day of maximum demand, the term "on-peak load time" is used, and for periods out of the maximum demand the term is "off-peak load time". In general, the periods are coincident, but for the case of this work, they are not.

The object of analysis in this article is the consumption, by the consumers, at the period of on-peak time tariff of the green modality, who were subjected to the tariffs of Table 1. For the company used in this case, this market represents 0,83% of the total consumer market. Even if the amount consumed is not representative within the total market of the company, the potential for revenue increase is high and, still, with no counterpart of cost increase. This matter will be explored further below.

The Figure 3 shows the consume behavior characteristic of this group of consumers.

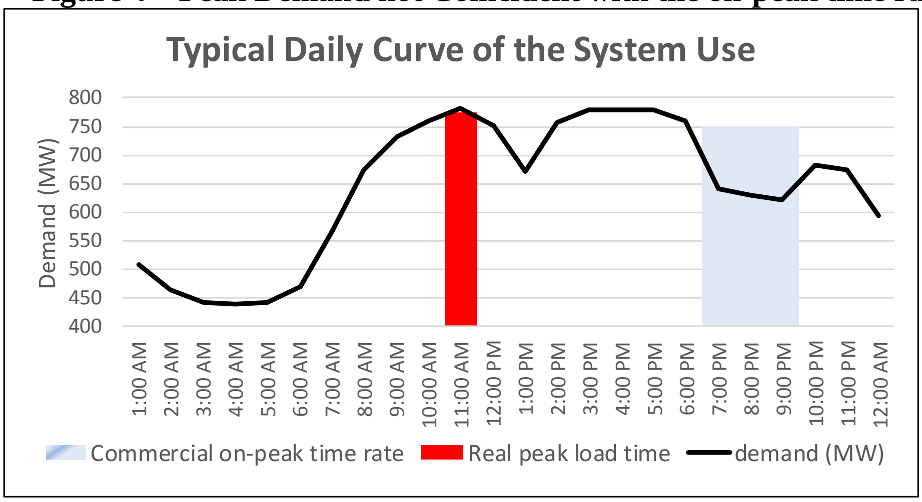
Figure 3 – Typical Behavior of the Green-Tariff Consumers



Source: Curves of Electric Energy Charge for Consumers.

Here is noticed that green customers perform a valley at on-peak time rate, that is, these consumers modulate their behavior due to the high tariffs applied at this time of day. On the other hand, from the analysis of the use of the system, it is observed that the assets were being used inefficiently, which means, with idle capacity, as shown in Figure 4 below.

Figure 4 – Peak Demand not Coincident with the on-peak time rate



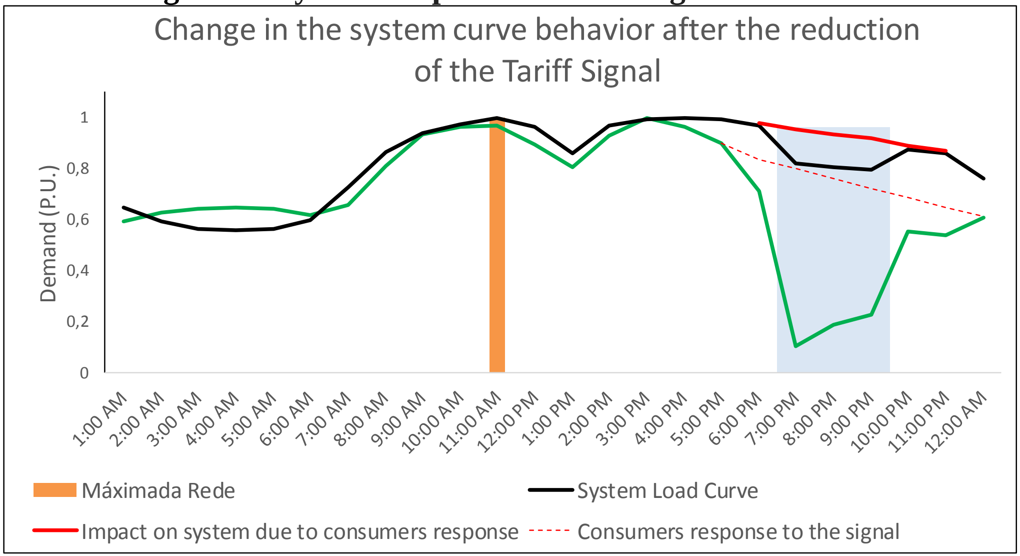
Source: Results of the characterization of consumers' electric energy use.

The maximum demand occurs at 11am, the on-peak time rate (higher prices) occurs between 6pm-9pm. This finding suggests that the peak price is not linked to the cost of grids expansion and could be reduced. So, if the system operates idly in the period between 6pm and 9pm, why should the green consumer be encouraged to reduce consumption at this time?

However, before proposing this signal reduction, some precautions should be taken. The shape of the curve shown in Figure 4 is influenced by the behavior of the consumers submitted to the current tariff signals, so when the signal is changed, the response of these consumers to the tariffs will be different, and may even change the time of peak demand. In other words, the change must be sufficient to induce better use of the capacity already installed, being careful to not shift the peak time to the period when the system presents a slack. If this occurs there will be a need for investment to meet this new schedule of maximum demand.

In order to circumvent this situation, the potential additional demand, equivalent to the withdrawal of the tariff signal of green consumers, was estimated individually to ensure that the current capacity of the system is sufficient to accommodate this additional market without the need for new investments. Figure 5 shows the result of this simulation[7], evidencing the increase in the demand of the system and in relation to the current demand of this group of consumers.

Figure 5 - System Response to Tariff Signal Reduction



Source: Simulation of consumer response to signal economy reduction

Figure 5 illustrates the extreme situation in which all green consumers respond to the reduction of the tariff signal with the maximum amplitude. The peak demand of the system remains at the same time, at 11:00am, so it is possible to state that, even with the maximum response from consumers, the reduction of the tariff signal to the grid supports the increase of the demand.

This is important in the following sense: distribution grids are complex and fairly branched. The figures presented illustrate the total curve of the distribution system, which is the sum of the demands of all the distribution grids. However, at the company level, more detailed analysis are needed in order to ensure that all grids forming the system are able to withstand the signal reduction and the consequent increase in consumption. In this study, 73 network segments (feeders) were analyzed, of which 80% of them supported the increase in demand from the reduction of the tariff signal, and the other 20% were in the plan to increase the company's natural capacity and, after this natural expansion, would support the increase in demand. Thus the reduction

[7] The data is normalized by the maximum grid demand that occurs at 11am.

of the tariff signal for consumers of the green modality did not imply in the increase of investments beyond what was already in the budget of the company.

To obtain this analysis, it is important to understand that consumers, in their vast majority industries, are able to respond to the reduction in the tariff signal. As shown before, the on-peak time rate for green consumers was 1.546 R$/MWh. For the daily period of application of these tariffs, the consumers either stop consuming or start using generators, mostly, fed by diesel oil, as a way of replacing the electricity supplied by the utility.

In order to know which tariff level would be competitive with these two behaviors (production stoppage or replacement by diesel generators), a survey was conducted with these consumers to identify the cost of these options to the electric utility company. The consumers who used diesel oil as an alternative were paying around 750 R$/MWh, what is almost half of the company's tariff. It was also identified in this research that consumers were willing to pay a higher than 750 R$/MWh price for electricity, so that they did not have to manage diesel generators, which is not their core business. Therefore, even if the grid is sized to support the increase in expected demand, the on-peak time rate must be reduced from 1,500 R$/MWh to around 1,000 R$/MWh in order to become competitive in relation to generation diesel oil.

In mid-2012, during the 2013 tariff review process, this concessionaire serviced 4.800 customers in the green mode. Due to the characteristics of these consumers, all had a potential increase in market in the high tariff period and all were analyzed. However, for the monthly follow-up after the tariff adjustment event due to the company's operational limitation, it was necessary to reduce the sample size. Thus, 218 consumers with the potential to respond to the tariff reduction were selected for monthly monitoring of the effects of the event.

In the past, the regulation allowed to offer two differentiated products to these customers (i) ECP (Complementary Energy of Peak) and (ii) EI (Incremental Energy of Peak), which are equivalent to cheaper energy packages available at on-peak time rates and offered due to the excess contracts of energy supply. The hypothesis was that customers who consumed this product replaced electricity by their own generators at on-peak time, so it is understood that these customers are more likely to re-consume energy. In total, 132 consumers were identified, representing 6,9% of the supply market. In addition, 86 others were selected in order of decreasing revenue potential. Thus, a total of 218 consumers were individually monitored. The energy consumption of these 218 consumers accounted about 8,3% of the total market. In terms of revenue, it corresponds about 6% of the annual revenue.

In April 2013, the utility tariff review was ratified and the new tariffs became effective. Table 2 shows the tariff change that occurred at that time.

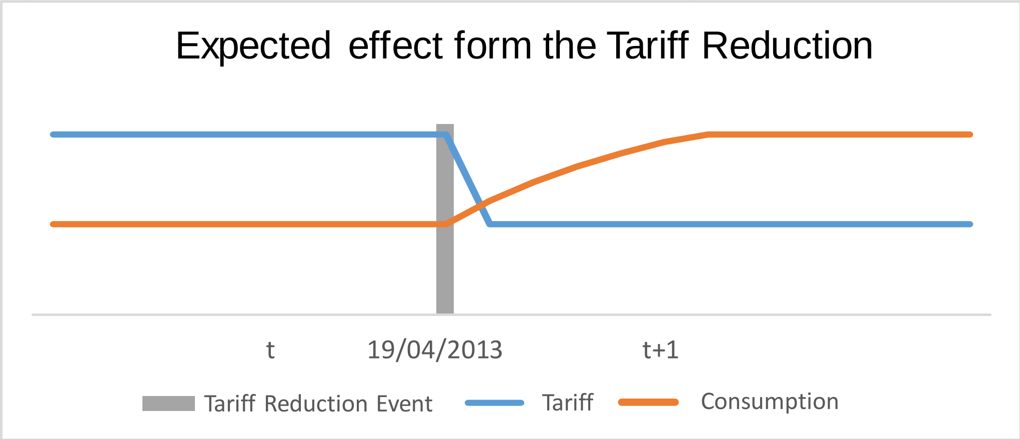
Table 2 – Change of Tariff since the Revision of 2013

Tariff Modality	Application period	Demand Tariff (R$/KWh)		Energy tariff (R$/MWh)		On-peak time Relation / Off-peak time	
		On-peak time	Off-peak time	On-peak time	Off-peak time		
		18h-21h	21h-18h	18h-21h	21h-18h	Demand	Energy
Green	Until 04/13	12,25		1.546,53	211,11	NA	7,33
	After 04/13	10,96		1.016,17	215,17	NA	4,73

Source: Tariff approved by National Electric Energy Agency.

From Table 2 it can be concluded that the tariff time signal fell from 7,33 to 4,73, reducing the tariff from 1.546 R$/MWh to 1.16,94 R$/MWh. The tariff change was not enough to reach the average cost of diesel production of 750 R$/MWh, but it entered a value range that makes the electric energy, provided by the company, competitive with the use of diesel generators, by eliminating of the operational responsibility that the industries have when opting to operate a plant with energy generated by diesel oil. Figure 6 illustrates the hypothesis adopted in this case study, that is, from the tariff reduction at on-peak time consumers are encouraged to increase the consumption of electricity in this period, replacing the diesel oil generation by electricity.

Figure 6 – Expected behavior since the economic signal reduction



Source: Personal creation

On April 19, 2013, the on-peak time rate was reduced, so it is expected, from this date, an increase in consumption at this time. This increase must occur gradually since the impact on consumer billing due to tariff reduction is only observed one to two months after the change, due to the commercial billing schedule. The new tariffs were applied since April 19, 2013. In this way, all energy consumed from this period was billed under the new tariff regime. However, depending on the individual billing date, the perception of falling tariffs occurred only one period after the effective tariff change.

The next section details the impacts and magnitude of these policies for an electric utility company.

EMPIRICAL STRATEGY

4.1 Database

The database was formed by information taken from the energy utility company, based on 218 customers in the period from 01/2012 to 05/2016. Consumers began to notice the change in tariffs from April 2013 at on-peak time. The results described below, in an aggregated way, seek to show the differences in consumption at on- peak time and at off-peak time after the change in tariff.

Table 2 – Analysis of Consumption at on-peak time and off-peak time

Increasement Accumulated	On-peak time		Off-peak time	
	MWh	Increasement %	MWh	Increasement %
05/12-04/13 – base line	11.226	0,00	506.010	0,00
09/12-08/13	12.149	8,21	511.348	1,05
12/12-11/13	14.168	26,20	519.392	2,64
03/13-02/14	16.706	48,82	522.482	3,26
06/13-05/14	19.804	76,41	525.076	3,77
09/13-08/14	21.513	91,63	523.476	3,45

12/13-11/14	21.888	94,97	521.452	3,05
01/14-12/14	22.024	96,18	521.685	3,10
02/14-01/15	21.913	95,20	518.626	2,49
Average	17.932	59,73	518.839	2,53

Source: Energy Utility Company Billing System.

On Table 2 can be seen that the cumulative consumption after the reduction of tariff at on-peak time had an average increase of 59,73% and in the off-peak time the average increase was of 2,53%. Based on the information after the tariff change, it is possible to identify an expressive effect at on-peak time consume.

From the analysis of the aggregated data it is observed that there is an indication that after the implementation of the tariff reduction at on-peak time there was an increase in the respective consumption. However, when it is analyzed the effect only after the change in the tariff policy, it is possible that components such as tendency, seasonality or even something not observed from each company may have influenced for more or less the consumption of the two energy modalities.

In order to control these effects and work with a previous and posterior evaluation of the reduction in the on-peak time tariff in relation to the consumption of off-peak time, it will be used the method of differences in differences that evaluates the variation from the second difference, as discussed next.

4.2 Differences in Differences Model

According to Peixoto (2012), the method of differences in differences is used in natural experiments (or almost experiments) in which an event occurs and allows creating two groups: (i) treatment and (ii) control, similar in several aspects, but only a group is affected by the event. The source of the shock event may, for example, be of a natural order (hurricanes, earthquakes), institutional changes (laws, popular programs), economic (price shock) and others.

For the data application in this study, the model of differences in differences is justified by the fact that there is the provision of information over time of distinct groups regarding the intervention that want to be estimated: the price reduction policy for energy consumption in on-peak time industrial mode. So, for this investigation there are information about 218 companies that consume in both modalities, on-peak time and off-peak time, generating 436 consumption information over time.

The principal hypothesis for the identification of the impact of tariff reduction at on-peak time rate consumption in relation to off-peak time rate consumption lies in assuming that in the absence of the tariff reduction policy, the trajectories of the consumption variables of on-peak time and off-peak time would bring parallel trajectories. In this way, any other shocks that could affect the trajectories of the variables of interest between the treated group (on-peak time rate consumption) and the control group (off-peak time rate consumption) would present the same influence. Thus, any deviations observed in the trajectories of the variables of interest between the two groups, in periods after intervention, can in fact be related to the effect of the policy on the directly affected modality of consumption.

In this paper it the following equation is estimated:

$$Y_{ijt} = \alpha_0 + \alpha_1 G_{ij} + \alpha_2 P_t + \alpha_3 G_{ij} * P_t + \varepsilon_{ijt} \quad \text{(Equation 2)}$$

Being: i=1,...218, j=1,...436 e t=01/2012,...,05/2016.

The dependent variable Y_{ijt} is the energy consumption from company i, in the modality j and in the period t. The variable G_{ij} is a binary variable that assumes value 1 for the consumption of company i in the modality of on-peak time consumption, and value 0 for the company i in the off-peak time consumption. The variable P is also a binary variable that assumes value 1 for all the observations of periods after 04/2013 (date of the reduction of tariff in the on-peak time consumption), and zero for the periods that precede that date.

The coefficient of interest to be estimated is α_3 that captures the difference of the conditional differences of the dependent variable between the two types of consumption (on-peak time and off-peak time) over time. In order to illustrate it, it is taken the four following conditional:

$$E[Y_{ijt}|G_{ij}=1,P_i=1]=\alpha_0+\alpha_1+\alpha_2+\alpha_3+E[\varepsilon_{ijt}|G_{ij}=1,P_i=1] \quad \text{(a)}$$

$$E[Y_{ijt}|G_{ij}=1,P_i=0]=\alpha_0+\alpha_1+E[\varepsilon_{ijt}|G_{ij}=1,P_i=0] \quad \text{(b)}$$

$$E[Y_{ijt}|G_{ij}=0,P_i=1]=\alpha_0+\alpha_2+E[\varepsilon_{ijt}|G_{ij}=0,P_i=1] \quad \text{(c)}$$

$$E[Y_{ijt}|G_{ij}=0,P_i=0]=\alpha_0+E[\varepsilon_{ijt}|G_{ij}=1,P_i=1] \quad \text{(d)}$$

Now, by applying the differences (a)-(b) e (c)-(d) there is:

$$\text{(a)}-\text{(b)}=\alpha_2+\alpha_3+\{E[\varepsilon_{ijt}|G_{ij}=1,P_i=1]-E[\varepsilon_{ijt}|G_{ij}=1,P_i=0]\} \quad \text{(e)}$$
$$\text{(c)}-\text{(d)}=\alpha_2+\{E[\varepsilon_{ijt}|G_{ij}=1,P_i=1]-E[\varepsilon_{ijt}|G_{ij}=1,P_i=0]\}. \quad \text{(f)}$$

Lastly, with the hypothesis of identification of the differences in differences method $\{E[\varepsilon_{ijt}|G_{ij}=1,P_i=1]-E[\varepsilon_{ijt}|G_{ij}=1,P_i=0]\}=\{E[\varepsilon_{ijt}|G_{ij}=1,P_i=1]-E[\varepsilon_{ijt}|G_{ij}=1,P_i=0]\}$, it is obtain α_3 from (e)-(f).

The effect verified by α_3, can also be estimated by β_1, through the equation:

$$Y_{ijt}=\alpha+\theta_i+\lambda_t+\beta_0 G_{ij}+\beta_1 G_{ij}*P_t+\varepsilon_{ijt} \quad \text{(Equation 3)}$$

This equation reflects the panel estimation with control of fixed effects and trend and was evaluated in four specifications as a way to evaluate the robustness to results. In the first one the effect was estimated from the control of fixed effects without evaluating trend and seasonality. In the second of the four specifications an interaction term between the binary variable that identifies the groups and a trend variable (t) is included. With this interaction it is allowed that the trajectories of the dependent variables have different trends between the two groups. In the third specification it was removed the interaction of the second and included dummies of months to control effects related to seasonal issues that may affect the types of energy consumption. In the fourth and final specification was included both the interaction and the dummies of months. The standard errors were estimated by the White correction process for the covariance matrix. In addition, three different samples were used to carry out the step described above.

In the first sample was used all the observations that was available. We call this sample "Full Sample". The second sample contains only information that is within the window of twelve months before and after 03/2013. This sample, we call “twelve months window”. Finally, the third sample contains observations within the window of six months prior and six months after 03/2013, identified by "six months window". That procedure was adopted in order to investigate if the price reduction effect, if any, presents some heterogeneous behavior over time.

In order to verify the robustness of the results was adopted two procedures. The first is what we call the "temporal placebo," which consists of estimating all the specifications used shifting the date of the event for periods prior to the actual change in the price of on-peak time rate. The idea behind this procedure is to verify the existence of previously non-parallel trajectories between the dependent variables of the two groups, which invalidates the hypothesis of identifying the impact of the method of difference in differences in this case. If the results observed in the main estimates are indeed significant and are capturing the effect on the energy consumption, when the estimates for periods before the change in price policy are made, it is expected the absence of statistical significance.

In this procedure was not use the information after 04/2013 in order to not contaminate the estimates of the temporal placebo with information from periods in which the intervention is already operating.

This investigation estimated the "temporal placebos" in two periods with different windows. The first is twelve months before the date of the intervention, 04/2013, with window from 04/2012 to 03/2013, while the second is six months before the intervention date, 03/2013, with window from 10/2012 to 03/2013.

Next, it is presented the results found for the three samples evaluated as well as the analyzes of temporal placebos.

RESULTS

In a way to understand the dynamics of consumption in the two modalities, before and after the change in the price of on-peak time tariff, the differences in averages were evaluated, before and after the policy of reduction of tariff for the two consumption modalities and right after the analysis of the two differences.

According to the results of Table A.1 and also Graph A.1 and Graph A.2 (check the appendix), there is an average reduction of 7% in off-peak time consumption, after the reduction of the tariff consumption in on-peak time. On the other hand, the on-peak time consumption had an increase of 69,20% when compared to consumption before the tariff reduction. However, in order to control effects such as seasonality or even individual company trends, regressions in second difference with three samples and four different specifications were estimated.

The results illustrated in Table A.2 show that for the complete sample, that is, with the analysis that refers to the whole period, from 01/2012 to 05/2016, with reduction of the price tariff in on-peak time rate on 04/2013, in the first specification without trend control and or seasonality, there was an increase of 76,76%. In the second specification, with trend control, the increase was 84,89%. When was inserted the seasonal control and removed the trend, the effect was 77,07% and finally, with the trend control and also seasonal, the effect was 81,01%.

In a second sample, from 05/2012 to 03/2016, twelve months before and twelve months after 04/2013, in the first specification, without trend control and or seasonality, the effect was an increase of 76, 59%, without control. With trend control, the effect was 65,34%. When controlling only the seasonality, the effect was 76,70% and when controlling both, the trend and the seasonality, the increase was 68,73%.

When the results were evaluated for a sample of six months before the tariff reduction shock on 04/2013, it was found a positive effect of 56,67% in the first estimate, soon after, with the trend control, the effect was 40,35% . When controlling only the seasonality, the effect was 61,38% and when the two elements were included in the control, the effect was 52,05%.

In order to test if the effect found actually refers to the effect of the tariff reduction on 04/2013, two simulations of effect were evaluated, a sample with the effect a year before and a sample in which the effect is distorting by six months before the real reduction. Based on Table A.3 (check the appendix), in the first sample the results found, for the four specifications, were not foun significant. Finally, with the simulation of the effect being six months before the real one, the results were also not significant and that for the four specifications evaluated.

Thus, after the tariff reduction, in the on-peak time rate consumption, there was an average increase of 52,05% in a smaller sample, with six months, 68,73% in a period of analysis of

12 months and 81,01% with the full sample. It indicates that consumers responded to the incentive generated by the fall in the tariff price.

This result shows that, based on the analysis of the microeconomic data obtained at the company level, the strategic use of the tariff structure can improve the operating condition of the electricity distribution companies, without any additional investments, which allows a better efficiency allocation of economic assets and consequently a higher profitability.

6. FINAL CONSIDERATIONS

The objective of this article was to test the consumer's response to a change in the hourly economic signal through electric energy tariffs and, from this response, to observe an improvement in the use of the installed capacity of electricity distribution assets, for the case presented in the period after April 2013 to May 2016.

The data presented indicate that there was an increase in consumption during the on-peak time tariff after the reduction of the tariff, that is, the consumer started to demand more electric energy from the distributor by not using diesel generators or reducing their production. In addition, the statistical tests were consistent, what indicates the robustness of the results and, therefore, the hypothesis tested in this article, the one that the use of the assets of the electric energy utility would improve since the change of the economic signal were corroborated by the empirical and statistical evidence presented in this paper.

The main implication of this study is that, after confirmation of the tested hypothesis, the electric energy utilities should deepen their studies on tariff structure, and verify if they are operating in a condition of allocative efficiency. The empirical results showed that electric energy consumers, object of this investigation, responded to the reduction of the tariff from 1.546 R$/MWh to 1.006 R$/MWh (a reduction of 35%), which increased consumption in 81,01% at on-peak time rates (off-peak real load time), putting aside the use of diesel generators at an average cost of 750 R$/MWh.

The main contribution of this work was to present, based on the analysis of the microeconomic data, obtained at the company’s level, that the strategic use of the tariff structure can improve the operating condition of the electricity distribution companies, without any additional investments. Also it showed how the policy evaluation tool can be used for rigorous evaluation of business policies. This approach is in favor with what is conventionally called "insider econometrics".

A limitation of this study is that, when applied to other companies, the results may not be similar to those presented here, since different companies may be operating at different levels of allocative efficiency. Thus, it is not intended to present a general and complete formula for improving the allocative efficiency of companies and their revenues and profits, but it is aimed to draw attention to the opportunity that economic signals offer and to the use of modern econometric analysis in order to evaluate important business decisions.

REFERENCES

BERGSTROM, T; MACKIE-MASON, J. K. **Some Simple Analytics of Peak Load Pricing.** Santa Barbara: Department of Economics, Santa Barbara University, 1991.

BOITEUX, M. Peak-Load Princing. **The journal of business,** Chicago, v. 33, n. 2, p 157-169, Apr. 1960. Accessed 07 October 2016, <http://www.jstor.org/stable/2351015>.

CREW, M.; FERNANDO, C. S.; KLEINDORFER, P.R. The Theory of Peak Load Pricing: A Survey. **Journal of Regulatory Economics**, Dordrecht, v. 1, p. 215-248, Aug. 1995. Accessed 18 August 2016, <http://opim.wharton.upenn.edu/risk/downloads/archive/arch241.pdf>.

DEPARTAMENTO NACIONAL DE ÁGUA, ESGOTO E ENERGIA – DNAEE. Eletrobrás. **Nova Tarifa de Energia Elétrica**: Metodologia e Aplicação. Brasília, 1985.

MUNASINGHE, M**. Pinciples of Modern Electricity Pricing**. Proceedings of IEEE, New York, v. 69, 1981.

NETZ, J.S.; **Price Regulation**: A (Non Technical) Overview. Indiana: Departament of Economics, Purdue University, 1999.

PEIXOTO, B.; PINTO, C.C.X.; FOGUEL, M.N. **Avaliação Econômica de Projetos Sociais**. São Paulo: Dinâmica, 2012.

RAMOS, D.S.; BRANDÃO, R.; CASTRO,N.J. **Porque o preço de energia varia entre as distribuidoras?** Rio de Janeiro: GESEL, Universidade Federal do Rio de Janeiro, 2012.

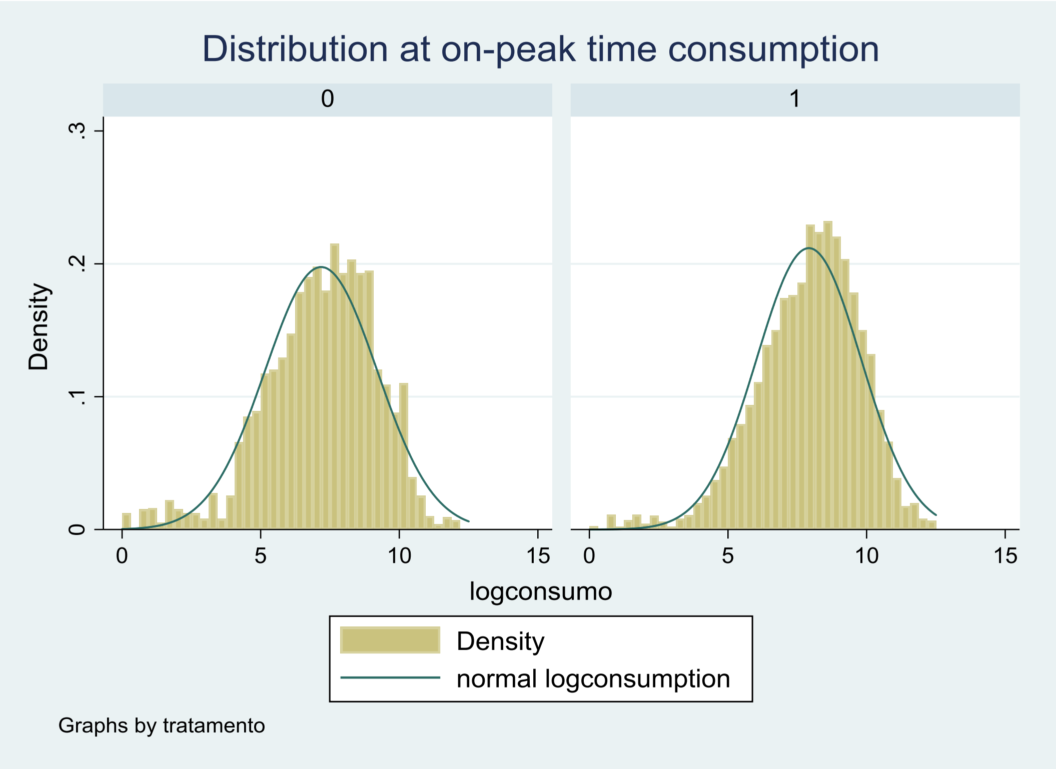
SHAW, K. L. **Insider Econometrics**: A Road Map with Stops along the Way. Stanford: National Bureau of Economic Research, Labour Economics, 2009.

TREMOLET, S.; BINDER, D. Body of Knowledge on Infrastructure and Regulation. **World Bank,** Nov. 2009. Accessed 05 September 2016, <http://regulationbodyofknowledge.org/>.

VISCUSI ET AL. **Economics of Regulation and Antitrust**. 3th ed. Cambridge: MIT Press, 2000.

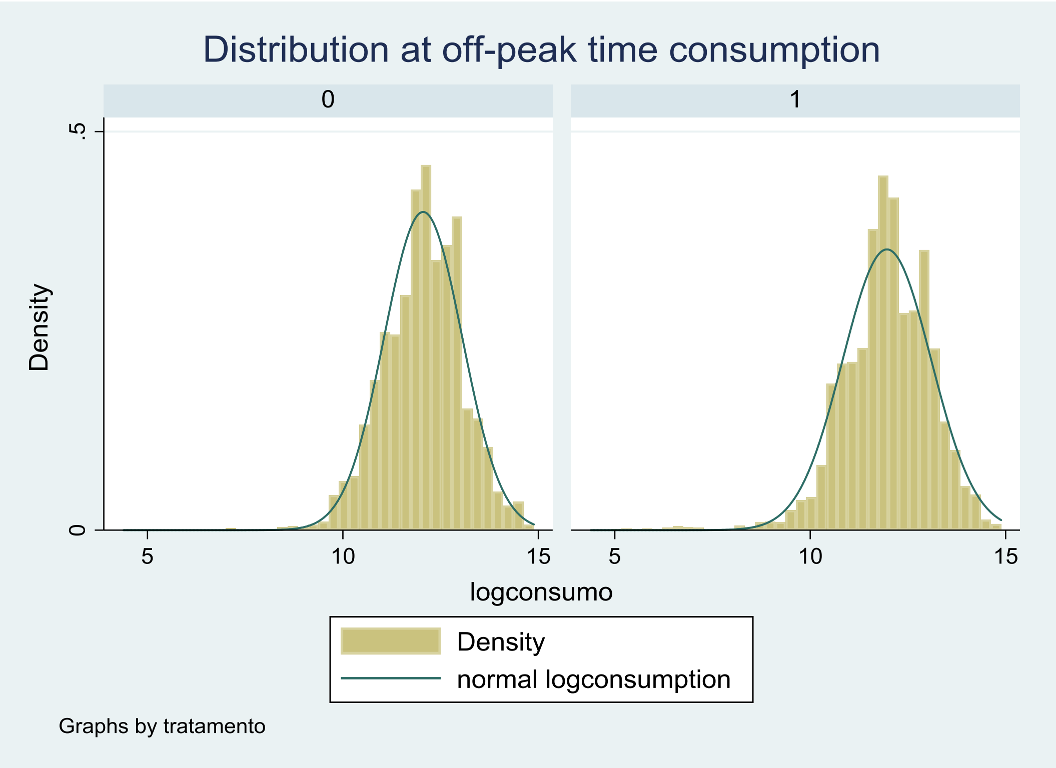
APPENDIX

Graph A.1 Distribution of on-peak time consumption before and after reduction



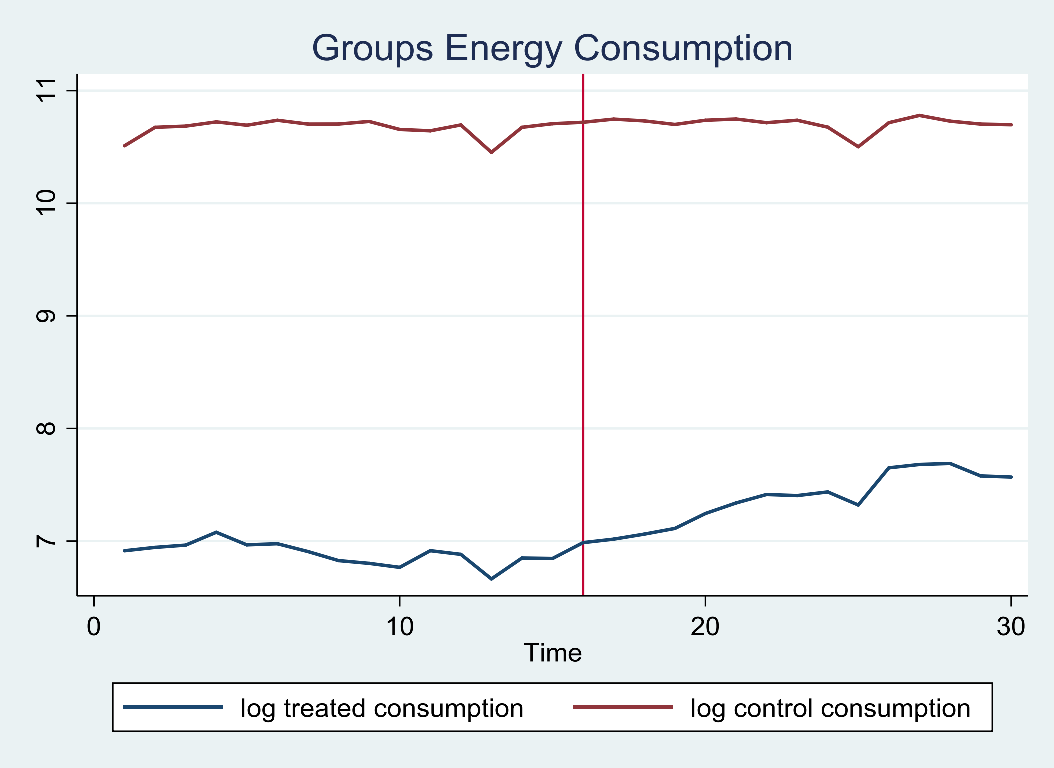
Source: Research results.

Graph A.2 Distribution of off-peak time consumption before and after reduction



Source: Research results. Power Consumption at ln tip and not tip

Graph A.3 – Energy Consumption at on-peak time and off-peak time



Source: Research results.

Table A.1 – Descriptive statistics of consumption in MWh

Consumption	Consumption before (deviation)	Consumption after (deviation)	Difference (deviation)	Statistic "T"
Off-peak time	269.977,50 (5.456,49)	251.075,50 (3.300,71)	18.902,08 (6.273,15)	3,0132 (0,000)
On-peak time	5.588,89 (232,621)	9.456,86 (221,034)	-3.867,975 (380,96)	-10,1532 (0,000)

Source: Research results.

Table A.2 Results for the reduction of tariff consumption of on-peak time

	Full Sample (01/2012 a 05/2016)				**Twelve months window (05/2012 a 03/2016)**				**Six months window (10/2012 a 09/2013)**	
	coef/se	**coef/se**	**coef/se**	**coef/se**	**coef/se**	**coef/se**	**coef/se**	**coef/se**	**coef/se**	**coef/se**
Effect	0,7676***	0,8489***	0,770***	0,810***	0,765***	0,653***	0,767***	0,687***	0,403***	0,520***
	(0,0892)	(0,0823)	(0,090)	(0,088)	(0,084)	(0,072)	(0,084)	(0,084)	(0,070)	(0,081)
Group	-4,8422***	-4,8997***	-4,844***	-4,872***	-4,938***	-4,880***	-4,939***	-4,898***	-4,816**	-4,886***
	(0,1006)	(0,0931)	(0,1015)	(0,099)	(0,100)	(0,096)	(0,100)	(0,101)	(0,099)	(0,104)
Constant	11,9949***	12,0781***	12,007***	12,051***	12,073***	11,929***	12,110***	11,994***	11,702***	11,897***
	(0,0381)	(0,0455)	(0,044)	(0,054)	(0,042)	(0,053)	(0,051)	(0,072)	(0,074)	(0,090)
R^2	0,789	0,789	0,790	0,790	0,807	0,807	0,808	0,808	0,817	0,819
Observation	21992	21992	21992	21992	10586	10586	10586	10586	6418	6418
Trend	No	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes
Seasonality	No	No	Yes	Yes	No	No	Yes	Yes	No	Yes

Source: Research results.

Table A.3 Results of placebos for the reduction of tariff consumption of on-peak time

	Placebo twelve months before (01/2012 a 03/2013)				Placebo six months before (01/2012 a 03/2013)			
	coef/se	**coef/se**	**coef/se**	**coef/se**	**coef/se**	**coef/se**	**coef/se**	**coef/se**
Effect	-0,043	-0,029	0,036	0,068	-0,080	-0,072	-0,039	-0,048
	(0,065)	(0,064)	(0,067)	(0,083)	(0,094)	(0,088)	(0,094)	(0,092)
Group	-4,876***	-4,883***	-4,953***	-5,041***	-4,876***	-4,876***	-4,906***	-4,906**
	(0,102)	(0,102)	(0,1062)	(0,118)	(0,121)	(0,121)	(0,125)	(0,125)
Constant	12,065***	12,080***	12,095***	12,067***	12,077***	12,089***	12,108***	12,039***
	(0,047)	(0,053)	(0,061)	(0,213)	(0,049)	(0,064)	(0,064)	(0,154)
R^2	0,840	0,840	0,845	0,849	0,844	0,844	0,844	0,819
Observation	6384	6384	6384	6384	5118	5118	5118	5118
Trend	No	Yes	No	Yes	No	Yes	No	Yes
Seasonality	No	No	Yes	Yes	No	No	Yes	Yes

Source: Research results.