# Just Do It:
# Temporary restrictions and new consumption habits

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**[PRELIMINARY AND INCOMPLETE]**
**[PLEASE DO NOT CIRCULATE]**

**Abstract**

I use a natural experiment to study how temporary restrictive policies can have lasting effects by changing consumption habits. I find that a 8-month compulsory rationing imposed to Brazilian households' electricity consumption led to a persistent reduction on electricity use of 20% even 9 years later. This effect is equivalent to a 58% increase in electricity prices. I find no effects of the restrictions on average wages or electricity price neither in the short nor in the long run. Micro-data on households appliance inventory suggest that the restrictions reduced the acquisition of new appliances in the long run. When controlling by these covariates, I still find that the restrictions reduced electricity consumption by 13% post the rationing. Hence, the main source of persistence seems to come from changes on the intensive margin of households electricity use, i.e., their actual consumption habits. At last, I use these findings to make a brief policy discussion.

*JEL codes: D12, O33, Q41.*

## 1 Introduction

There is a vast literature looking at the ongoing impacts of policies (and nudges) which are very effective to shape consumers behavior, basically by shifting the demand curve. For example, one can give incentives to increase gym attendance (Charness and Gneeze, 2009; Acland and Levy, 2011), use prices and public appeals to reduce electricity use (Reiss and White, 2008) or explore social comparison to reduce households electricity or water use (Allcott, 2011a; Costa and Kahn, 2010; Ferraro and Price, 2011). However, once the policies are discontinued, most

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of their effects cease. As policy makers, we seek log run effects and, ideally, we would like to be able to design a one-time interventions with sustainable effects. In this paper, I ask if temporary restrictions on households electricity consumption can have lasting effects on how people use electricity. I shed light on the mechanisms behind it, and use them to speculate about a policy insight.

I am not the first to study how long run effects could emerge from temporary policies. Charness and Gneeze (2009) show that short run incentives to gym attendance have some lasting effects through habit formation. However, these effects disappears reasonably fast over time once the incentives are discontinued (Acland and Levy, 2011). Dupas (2010) finds long run effects on the adoption of bednets in Kenya, and argue that experience or social learning are the drivers of this persistence. A similar result is found by Bryan, Chowdhury and Mobarak (2011) in an experiment in which they provided incentives for seasonal migration in Bangladesh. Both papers find that information by itself is not effective in changing behavior, but that individuals who experienced a different behavior for a period - the bednets or the migration - are more likely to stick to the new behavior pattern. In a public good context, Kremer and Miguel (2007) could not find evidence of persistence in the intake of deworming medicines. They find that substituting subsidies to the drugs by a sustainable worm control measure was not effective to affect behavior permanently, concluding that it "appears unrealistic" to seek a policy with long run effects in a public goods provision setting.

In this paper, I provide evidence of a policy that, by changing household consumption habits, maintained the electricity demand shifted down almost a decade later. I use a large natural experiment happened in Brazil, when due to unexpected low water levels on the reservoirs of the hydroelectric power plants, the Brazilian government imposed a temporary restriction on households electricity use. Without further notice, in June 2001, the households from 17 of the 25 Brazilian states had to reduce their consumption by 20% relative to their historical consumption. The restrictions would last while the reservoirs were dry. After 8 months of rationing, the restrictions were removed. As I describe in detail in Section 2, I interpret this event as a natural experiment because the treatment allocation (both timing and regions) was determined mainly by weather conditions.

It is important to use experiments to evaluate demand response policies, such as the rationing. If the policy implementation is endogenous with the actions of the targeted individuals, unobserved variables would very likely bias the results, making the policy evaluation innocuous. Also, despite the reduced control on the experimental design one have when working with natural experiments, I believe that this methodology better suits the study of policy's long run effects. When looking at persistent effects of a policy on individuals behavior, one needs to take into account general equilibrium effects which may emerge, for example on prices and income. Small randomized control trials are limited to address these points.

In order to identify the effects of the restrictions imposed on households, I use the non-rationed states as a control group for the rationed states in a differences in differences estimation. My exogeneity assumption is that the treatment allocation was not correlated with the potential electricity consumption of households on both areas. Since the rationing was followed by a national informative campaign led by the government, and brought forward the presidential campaign, the issues related to energy saving became very salient in the country as a whole. The government also reduced taxes of all energy efficient appliances. Hence, I understand that the treatment that I capture in this paper is the rationing by itself: the restrictions on the households electricity use. It is worthy to mention that the electricity prices are centrally regulated by the government, and were not heavily affected as will be shown. Since the country is very heterogeneous, and due to data availability, I restrict my analysis to the most developed part of Brazil, which are the states from the south, southeast and midwest.

Using administrative data, I find that electricity consumption dropped around 30% in the rationed states relative to the non-rationed states during the eight months period starting in June 2001. Figure 1 presents the average household electricity consumption (in MWh) over time for the rationed and non-rationed states - the vertical lines highlight the rationing period. I find that from March 2002 until September 2010, consumption dropped on the rationed states by 20% relative to the non-rationed states. This long run effect is equivalent to a 58% price increase. The energy saved adds up to 23 months of pre-rationing consumption, which worth roughly the average wage in a whole month in the region. Results are not affected when controlling for income and electricity price.

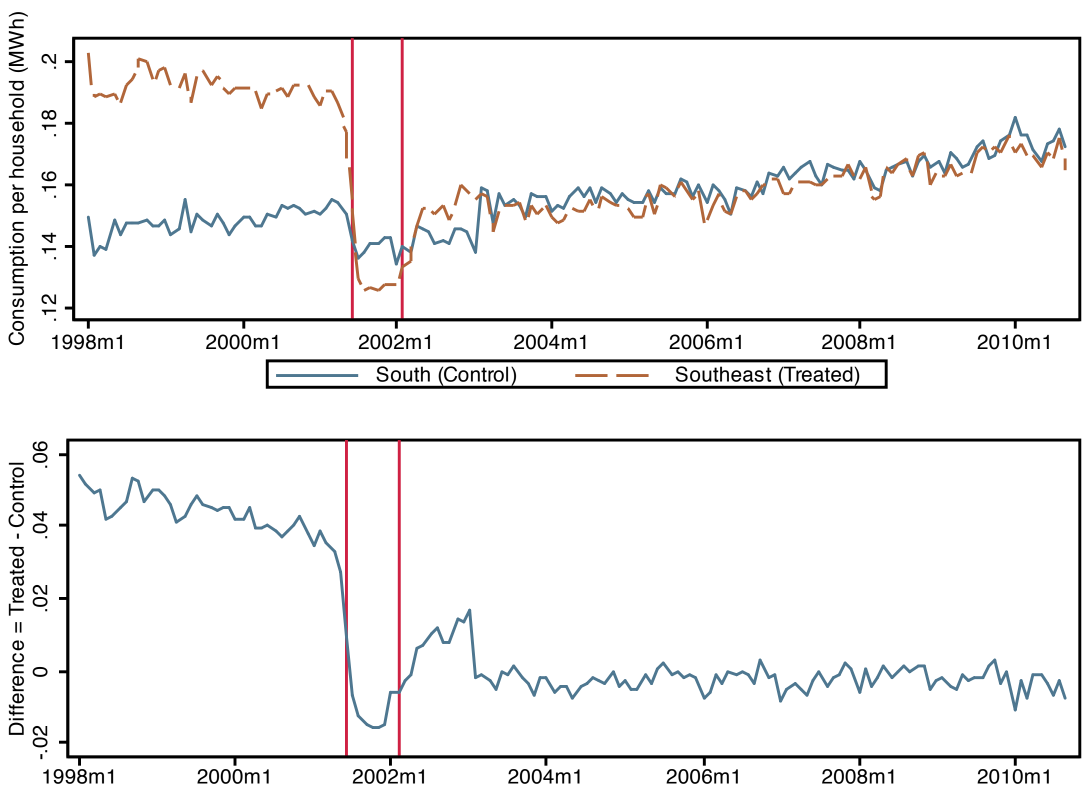


Figure 1: Average households electricity consumption in MWh (seasonal adjusted)

As we can see in the figure, the non-rationed south reduced its consumption during the rationing as well, even not facing any restrictions. As I argued previously, this may be due to the public information campaigns and subsidies. Again, *my objective is to estimate the effects of the rationing by itself*, not the effects of information campaigns and subsidies. Moreover, the main effort of this paper is to identify through which mechanisms these restrictions affected household electricity consumption permanently.

In a classical model, individuals must change their behavior when facing unexpected binding constraints. Revealed preference would tell us that people cannot be better off under the tighter constraints and that individuals would return to their initial consumption once the restrictions are dropped. However, if we consider that *technology substitution* and/or *habit formation* can occur during the period with extra restrictions, the results from revealed preference do not hold. In this case, people may end up not returning to their original consumption pattern once the restrictions are withdraw, as we observe here.

In order to understand the mechanisms behind this permanent drop on consumption, I first need to understand why electricity use looked so different in these two regions until 2001. To do so, I compare the main determinants of electricity consumption: wages, prices and appliances inventory. Using official data, while I find no significant difference on the electricity price paid in these regions, I see that the average households in the southeast was richer than the average southerner one. This evidence is consistent with the idea that electricity is a normal good. I use household level micro-data from the Brazilian Household Budget Survey to construct indices summarizing the quantity and the vintage of appliances of these households. I observe no statistically significant difference in the quantity of fridges, freezer, air conditioners and televisions owned by the households in the two areas, and that these appliances were more likely to be new in the southeast than in the south. This suggests that the higher electricity use in the southeast was given mainly by the intensive margin of consumption, which are the consumption habits actually speaking.

I find that the rationing had no effect on wages and electricity price both in the short and long run. That is, after 2002, the households in the southeast were still richer and faced similar electricity prices as before 2001. Even so, electricity consumption dropped. I find no effect on the quantity of appliances in the short run, but that the rationing (not significantly) reduced the quantity of appliances in the southeast relative to the south in the long run. At the same time, appliances in the southeast became relatively less likely to be new both in the short and in the long run. This is evidence that households in the southeast decelerated the acquisition of new appliances over time. Furthermore, by estimating the difference in difference of electricity consumption controlling for wages, prices and the stock of appliances, I find that the restriction on electricity consumption was responsible for a drop of 13% on electricity use in the southeast relative to the south. These findings together suggest that the main responsible for the long run effects were new - and persistent - consumption habits.

To my best knowledge, there is no documented evidence of programs that triggered long run effects on electricity consumption, specially by changing consumption habits. I believe that we can draw some intuition from this event for policy speculation. Temporary consumption restrictions could be particularly useful when designing demand response programs on settings where individuals do not have a perfect account of the marginal costs and benefits of their actions, such as energy and environmental issues (Allcott, 2011b). Furthermore, this is a large scale experiment which accounts for possible general equilibrium effects, such as reduction of economic activity and price changes, which are crucial when evaluating long term policies.

This draft is organized as follows. On Section 2, I describe the electricity rationing and argue that it can be read as a natural experiment. On Section 3, I describe the data and the empirical strategy. Section 4 contains the results, where first I scrutinize the pre-rationing difference between the regions, and then I analyze the effects of the rationing on electricity consumption and other relevant variables. I close with a brief policy discussion in Section 5.

# 2 The Electricity Rationing

The electricity generation capacity of Brazil heavily relies on its river system. From 1998 to 2000, 94% of the electricity used in the country was generated by hydroelectric power plants (ONS, 2003). Although this is one of the cheapest and least pollutant energy sources, it makes the system exposed to adverse weather conditions, as it hinges on the stream-flow of the rivers serving the power plants.

In Brazil, the stock of generation units are centrally programmed and dispatched by the National System Operator (ONS), who is responsible for keeping the system balanced, guaranteeing that supply meets demand. Due to Brazil's size and heterogeneity, the electricity system is divided into four subsystems according to hydrological, social and economic characteristics which are: South (S), Southeast/Midwest (SE), North (N), and Northeast (NE).[1]

The rationing was a consequence of an unbalanced system in which, without extreme measures, the electricity supply would not meet the demand. Naturally, both demand and supply factors could lead the system to this critical situation. In this section, I try to understand what drove the system to an eminent collapse, and more specifically, if demand factors were pivotal in this process.

Table 1 shows both the demand forecast of ONS for the period 1998 to 2000, and the realized demand in this period. As we can see, the realized demand was bellow the expected in the period. That is, the system was supposed to support a load even higher than the realized in the period. As the official report about the rationing concludes, *no demand factor contributed to the unbalancing of the system and the 2001 collapse* (Kelpman, 2001).

| | **1998** | **1999** | **2000** | **Total 98-00** |
|---|---|---|---|---|
| *Expected Demand* | 332 | 347 | 361 | 1039 |
| *Realized Demand* | 333 | 339 | 357 | 1029 |

Source: PDE (1998) and ONS.

Table 1: Evolution of expected and realized demand (TWh)

Supply factors were the main responsible for the 2001 collapse. Consecutive years of reduced stream-flow, a consequence of the climatic phenomenon *El Niño*, gradually reduced the reservoir levels, specially on the subsystems SE and NE. Figure 2 shows the series of the reservoirs level as a percentage of their maximum capacity for the subsystems SE and S, from 1997 to 2001. As we can see, the reserve level on the subsystem SE decreased almost monotonically in that period, while we cannot observe nothing unusual in the S, except in 2000. In January 2000, the reservoir levels in the power plants of the SE were slightly above 30%, at similar levels to the one on the beginning of 2001. As Kelpman (2001) points out, by January 2000 the probability

[1]These subsystems are connected by transmission lines that allow some level of energy exchange between subsystems, mainly to explore hydrological complementarities between them, and to reduce the risk of default of the system.

of a default of the subsystem SE was sizable.[2]However, above average stream-flow on the second half of the year guaranteed electricity supply for 2000.[3] It is worth to mention that, despite all the risk of collapse, no concrete measure was taken by the government in 2000.

In 2001, however, Brazil was not that lucky. The wet season on the subsystems SE and NE were extremely unfavorable, leading the reservoir back to critical levels. As can be seen on Figure 3, the seasonal stream-flow that fill the reservoir on the beginning of each year were not observed in the subsystem SE. In fact, 2001 was the lowest stream-flow level ever recorded by the ONS during that period of the year. As a consequence of the critical reservoir levels in the subsystems SE and NE, in March 2001 the ONS officially asked the federal government for an intervention in order to reduce demand by 20% on all states of these subsystems. The government initially tried to develop a national plan to boost thermal generation (Priority Thermal Program). However, it was not successful, and in April 2001 the load reduction program started to be designed. In June 2001, the restrictions on household electricity consumption were implemented, and in February 2002, they were withdraw. I present a timeline with the events on Appendix B. The states from the subsystem S and N were not rationed.

### Restrictions on electricity use

Households were asked to reduce their electricity consumption to at least 80% of their average consumption on the previous year using a 3-month window. I.e., each household should consume in June 2001 at most 80% of his average consumption on May, June and July 2000. Those who did not meet their targets would face tariffs 15 times greater than the regular one.[4] Households who ignored the restrictions and did not meet the target would receive a warning at first and, after that, their electricity would be cut. Households who manage to save more than the 20% received bonuses for the extra energy saved. Initially, bonuses were on the proportion of 2 to 1, and later of 1 to 1.

All segments of consumers were subject to the restriction, except those with consumption bellow 100 kWh. The government also started a national campaign to provide information to the population on how to save energy. In an effort to stimulate the use of energy efficient appliances, such as fluorescent light bulbs, these goods had their taxes exempt.

[2]On a technical report published in 1999 (Nota Técnica ONS-DPP 059/1999), ONS presented simulations with 66 possible hydrological scenarios for 2000 based on the actual reserve levels at 30 November of 1999. The report shows that the reservoir levels in some regions would hit zero (i.e., zero energy reserve) in 9 of these scenarios. This represent a risk of default of the system equal to 14%, way above the 5% required by the regulator.

[3]As can be seen on Figure 3, on the second half of 2000, the stream flow reached 160% of the historical average for the period in the SE, and peaked 220% in the S.

[4]In Brazil, electricity utility companies have the concession under an area and they are the only suppliers in that area. The electricity retail market is not competitive, and the household electricity tariffs are set by the regulatory agency (ANEEL).

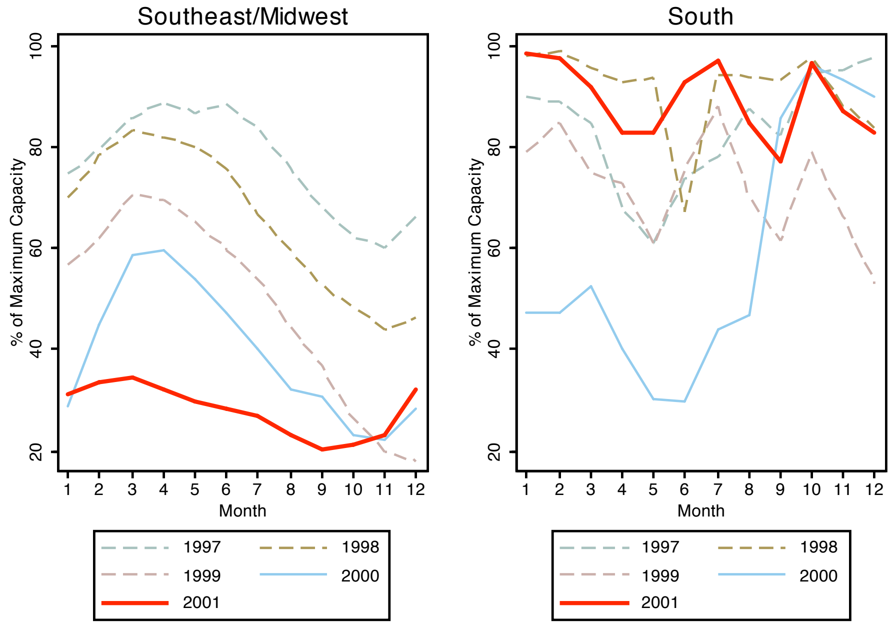


Figure 2: Reservoir levels on subsystems SE and S, as a percentage of their maximum capacity (ONS)

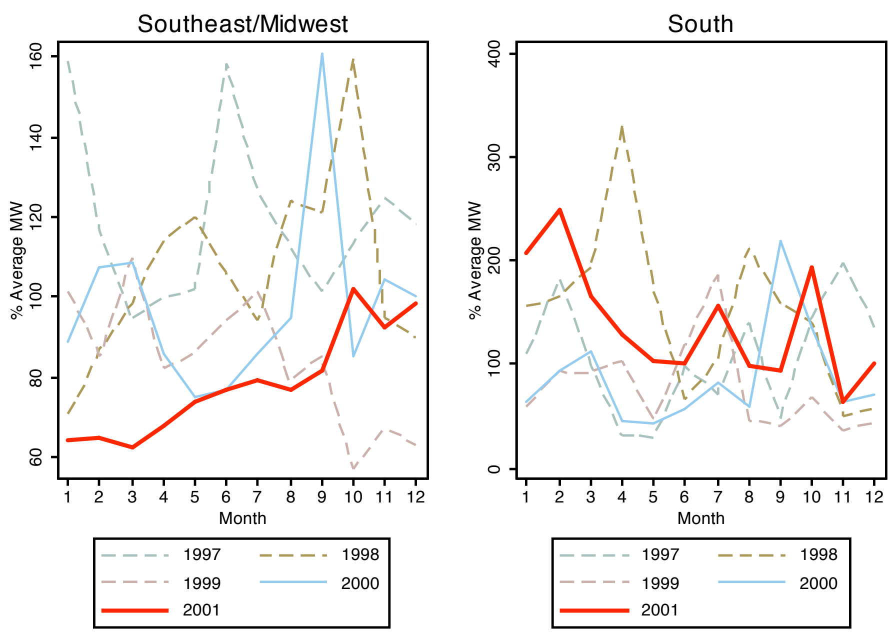


Figure 3: Inflow energy in subsystems SE and S (ONS)

| | S | SE | MW | N | NE |
|---|---|---|---|---|---|
| Monthly electricity use per house (kWh) | 154.9 | 200.7 | 165.8 | 146.9 | 103.2 |
| Households with electricity (%) | 97.9 | 98.6 | 95.6 | 79.5 | 86.6 |
| GDP per capita (R$) | 7650 | 8713 | 6498 | 3872 | 2998 |
| Population (Mi) | 25.1 | 72.4 | 11.6 | 12.9 | 47.7 |
| Urban Population (%) | 80.9 | 90.5 | 86.7 | 69.9 | 69.1 |
| Ave. Temperature (Summer) ($^oC$) | 23.2 | 23.5 | 25.1 | 26.2 | 26.1 |
| Ave. Temperature (Winter) ($^oC$) | 19.4 | 21.5 | 24.4 | 26.2 | 25.2 |

Table 2: Summary statistics of the natural regions in 2000 (Census and Eletrobras)

As it will become clearer on the next section, my identification strategy hinges on the assumption that demand factors are not correlated with the the timing and geographical allocation of the rationing. I believe that there are strong evidences to support this assumption: a series of adverse weather conditions led the system to an eminent collapse in 2001, urging immediate measures of load reduction. Also, as pointed by Kelpman (2001), if the hydrological conditions of 2001 had happened in 2000, the country would have faced an electricity shortage in 2000 even stronger than the one of 2001, because the south would have been affected as well.

We can see in Table 2 that the regions in Brazil are very heterogeneous. We can roughly split the country in its more developed part (south, southeast and midwest), and its less developed part (north and northeast). These two parts are very different and it would be difficult to compare them. In this paper I restrict my attention to the richer part of Brazil, and use the subsystem south as a control group for the the subsystem southeast/midwest. I do not compare the northern subsystems with the southerners ones because these areas are extremely different, and they were at different development stages.[5] I do not compare the north with the northeast because I do not have baseline data for the north.

# 3 Research Design

## 3.1 Data

I build a series of average monthly electricity use per household officially connected to the grid for each natural region between 1998 and 2010. I have total monthly household electricity consumption per utility company from January 1998 to September 2010 (Eletrobras, 1998-2002, and the Brazilian Regulatory Agency ANEEL, 2003 on). Monthly data for the number of consumption units (households) per utility company was obtained with ANEEL for the period

[5]While the electricity grid was already developed in the southern states (more that 95% of penetration in 2000), it was expanded in the northern states during the beginning of this century. In this period, the federal government lunched the program *Luz Para Todos* (Light For Everyone), which aimed to bring electricity to every household in the country. This program connected to the electric grid many new households from the poorest areas, mainly the northern states. Since the electricity grid was already reasonably developed in the S and SE, these states were not significantly affected by this program.

from 2003 to 2010. For the remaining years, I use the number of households connected to the grid per region from PNAD/IBGE and the National Census 2000.[6]

Data on households appliances inventory (with quantity and vintage information) comes from the Household Budget Survey (POF/IBGE). This is a household level survey that contains information on consumption and households characteristics from around 60 thousand households in three points in time 1996/1997, 2002/2003 and 2008/2009.[7]

Average household electricity tariff per region, weather and generation data are from the National System Operator (ONS). Further data used is average worker's wage (RAIS/IBGE), and household price index INPC per region (IBGE).

## 3.2 Identification Strategy

I am mainly interested in identifying whether the restrictions on electricity use affected consumption during the rationing and after its tenure. My main strategy is to use the non-rationed states (subsystem south) as a control group for the rationed states (subsystem southeast) in a difference in differences estimation. Let $Y_i(Treated_i)$ be the household $i$ consumption decision given that $i$ was $Treated_i$ or not. My exogeneity assumption is $Treated_i \perp (Y_i(0), Y_i(1))$. In words, the treatment allocation (the region and the timing of the rationing) is not correlated with the potential consumption of the households. Indeed, the evidences described on the previous section suggest that demand factors did not triggered the electricity shortage, supporting this assumption.

In my main specification I regress the following equation using random effects clustered by region[8]

$$Y_{it} = \alpha + T_i + \gamma t + \gamma_D During_t + \gamma_P Post_t + \beta_D During_t * T_i + \beta_P Post_t * T_i + \gamma X_{it} + \epsilon_{it} \quad (1)$$

where $Y_{it}$ is the log of average house electricity consumption in region $i$ at time $t$, $T_i$ is treated regions fixed effects, $\gamma$ is the time trend, $During_t$ is a dummy equal to one for the period between June 2001 and February 2002, $Post_t$ is a dummy equal to one for every period after February 2002, and $X_{it}$ is a set of control variables: average real wage, electricity price, appliance quantity and vintage indices.

The micro-data contains the quantity and the age of each appliances the household has. Appliance's age is an estimative, so it is subject to severe measurement erros. I attenuate this by creating two dummy variables: New and Old appliances. *New* is equal to one if the newest appliance has at most 2 years old ($New \equiv \mathbf{1}\{age \leq 2\}$).[9] *Old* is equal to one if the newest appliance has more than 5 years old ($Old \equiv \mathbf{1}\{age > 5\}$). I construct appliances summary

[6] The number of houses connected to the grid is monotonically increasing. I smooth the yearly data from 1998 to 2002 linearly to avoid discontinuities.

[7] This is a national survey that has the main objective to draw a picture of the assets and consumption behavior of the population in order to calculate the weights of the official inflation rate.

[8] Since electricity consumption is serially correlated and there exists common group errors, weather for example, the standard errors estimated by standard OLS are biased. I correct this bias by clustering standard errors by region, following Bertrand et al (2004). Using this cluster-specific random effects model the coefficients estimated are consistent and more efficient than standard OLS. The underlining error assumption is that $\epsilon_{it} = \alpha_i + \varepsilon_{it}$, where $\alpha_i \sim [0, \sigma^2_\alpha]$ and $\varepsilon_{it} \sim [0, \sigma^2_\varepsilon]$, as in Cameron and Trivedi (2005). I also use RE clustering by treated region, and OLS clustered by region. Results are not sensitive to the specification.

[9] This threshold was picked such that for the observations from 2002/2003 cohort, New means that the

indexes to aggregate information of different appliances on a single index, as Katz, Kling and Liebman (2004).[10]

The parameters of interest are $\beta_D$ and $\beta_P$. The effect of rationing on electricity consumption during the rationing is captured by $\beta_D$, and $\beta_P$ measures the rationing effects from March 2002 until September 2010. The controls $X_{it}$ are important not only for their effect on the standard errors, but also because they capture the effects of the rationing on electricity consumption net general equilibrium effects. I also estimate difference in difference for these controls to check how they were affected by the rationing.

Naturally, the credibility of these estimates hinges on having a suitable control group for our rationed households regarding their electricity consumption pattern. The extent that the south is indeed a valid control group for the southeast depends on the baseline characteristics of these two regions and how the two regions were changing over time. I access these differences (or similarities) in two directions: (i) by checking if the relevant variables were following parallel trends in these two regions; and (ii) by understanding the differences on the level of these variables before mid 2001 and after 2002.

### 3.2.1 Baseline Analysis

I test the parallel trend hypothesis - that treated and non-treated areas were following common trends before the rationing - by estimating the following OLS regression

$$Y_{it} = \alpha + T_i + \delta t + \delta_T t * T_i + \gamma X_{it} + \epsilon_{it} \tag{2}$$

where $t$ is the time trend, $\delta_T$ the time trend specific to the treated areas, $T_i$ is treated region fixed effects, and $X_{it}$ is a set of controls as average real wage and electricity price. Again, I cluster errors in regional level. The null hypothesis of common trend is that $\delta_T$ is equal to zero. I also test this hypothesis for the control variables.

In order to analyze the pre rationing differences on the levels of the variables I regress each variable on a constant and $T_i$, using random effects clustered by region.[11] The null hypothesis is that $T_i$ is not significant, and the rationed areas and non-rationed areas were equal before June 2001.

appliance was bought in 2001 or 2002. This is the closest I can get to a variable asking “Did you bought your appliance during the rationing”.

[10]These indexes are the equally weighted average of z-scores of each variable. These z-scores are calculated by subtracting the control group mean and dividing by the control group standard deviation. Missing values of households who owns at least one appliance are inputed at the group mean.

[11]I avoid using a t-test or a Wilcoxon rank-sum test, because both rely on the assumption that the observations are independent, and the variables here are all (potentially) correlated over time.

# 4 Results

## 4.1 Baseline Analysis

### 4.1.1 Parallel Trends

Table 3 shows the results from the parallel trend hypothesis tests based on equation (2). In the pre rationing period, I fail to reject that households' electricity use in both regions were following a common trend, even when controlling for wages and prices. I also fail to reject that prices in treated and non-treated areas were following a common trend before the rationing. I do observe that average real wage in the southeast was increasing relative to the southern one, despite both were getting poorer over time. This difference is statistically different from zero, however it represents a small difference: real wage was falling roughly around 3.2% and 1.8% a year in the south and southeast, respectively.

| | **Pre Rationing** | | | | | **Post Rationing** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *Electricity Use Per Household* | | | *Real Wage* | *Elect. Price* | *Electricity Use Per Household* | | | *Real Wage* | *Elect. Price* |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| $\delta_T$ | -.0003 | -.00029 | -.00023 | 11.70** | .001 | -.0001** | -.00005 | -.00005 | 2.52 | .0002 |
| | (.00011) | (.00010) | (.00009) | (.091) | (.001) | (.00000) | (.00002) | (.00003) | (5.39) | (.0007) |
| $\delta$ | .0002** | .00020* | .00040+ | -26.39** | .003** | .0003** | .00035* | .00034* | 16.41** | -.003** |
| | (.00000) | (.00004) | (.00010) | (.000) | (.000) | (.00000) | (.00006) | (.00006) | (.000) | (.000) |
| Wage | | Yes | Yes | | | | Yes | Yes | | |
| Price | | | Yes | | | | | Yes | | |
| *Mean* | | | | *798.3* | *.091* | | | | *759.5* | *.102* |
| N | 123 | 123 | 123 | 12 | 12 | 312 | 312 | 312 | 24 | 24 |
| $R^2$ | .965 | .965 | .968 | .928 | .865 | .781 | .790 | .790 | .958 | .583 |

Note: Standard errors clustered by region in parentheses. Regressions with constant and region FE. Observations: 123 Pre and 312 Post. ** p<.01, * p<.05, + p < .1

Table 3: Testing Common Trend Hypothesis

### 4.1.2 Pre-Rationing Difference

Table 4 shows the average electricity use in the different regions in different time windows. We can see that before June 2001, the average household in the southeast used to consume almost

30% more electricity than the average household in the south. However, I fail to reject the equality between these regions performing a cluster-specific random effects regression, as on Table 5.

| | **Pre** | **During** | **Post Rationing** | **Difference (Post - Pre)** |
|---|---|---|---|---|
| *Southeast* | .192 | .130 | .158 | -.033 |
| *South* | .148 | .140 | .160 | .012 |
| **Difference** | .044 | -.010 | -.001 | **-.045** |

Table 4: Average Electricity Use per Household (MWh)

A first question that arises is: where does this difference initially comes from? I investigate the main determinants of electricity consumption: income, price and appliances inventory. Table 5 presents the sample averages and the results from a simple regression of these different variables on a dummy for the treated region . We can see that wages were significantly higher and electricity prices were (not significantly) lower in the southeast than in the south. Data on the inventory of the four appliances responsible for the biggest share of consumption (fridges, freezers, air conditioners, and televisions) I have data on seem to go against the bigger consumption in the southeast. Households in the southeast had a (not significantly) smaller number of appliances than in the south, these appliances were more likely to be new, and as likely to be old. As we can see on columns 2-4, the electricity consumption gap goes to zero, getting even negative, when we control for these variables.

In sum, households in the southeast had higher wages and used to pay roughly the same electricity price. This, by itself, could explain the higher electricity consumption level, since electricity can be thought as a normal good. More specifically, evidence suggest that households in this region have a lighter stock of appliance than the southern ones, such that this difference in consumption pattern would be given by the intensive margin of consumption, if they exist at all.

As these numbers show, the two regions were never identical. However, electricity prices and wages seemed to be following a similar evolution before the rationing. This makes me comfortable with using the south as a control group for the southeast regarding households electricity consumption.

Table 6 mimics Table 5, but restricting the sample to the post rationing period. We can have a rough intuition of the main results from the paper by looking at Tables 3 to 6. We see that the households in the southeast were still richer and paying similar prices than the southerners after the rationing was over. Even so, they have a smaller electricity consumption even controlling for all these variables.

| | *Electricity Use Per Household (MWh)* | | | | *Real Wage* | *Elect. Price* | *Quantity Index* | *New App. Index* | *Old App. Index* |
|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| Treated Region | .029 | -.002 | .000 | -.003 | 142.7** | -.005 | -.070 | .055* | -.016 |
| | (.033) | (.007) | (.008) | (.006) | (30.4) | (.003) | (.073) | (.017) | (.012) |
| Real Wage | | Yes | Yes | Yes | | | | | |
| Electricity Price | | | Yes | Yes | | | | | |
| App. Indices | | | | Yes | | | | | |
| *Mean in the control region* | .148 | | | | 704.9 | .095 | 0 | 0 | 0 |
| N | 123 | 123 | 123 | 123 | 12 | 12 | 8423 | 8423 | 8423 |

Note: Standard errors of RE estimation clustered by regions/state in parentheses. Regressions with constant. Appliances: fridge, freezer, AC, and TV. ** p<.01, * p<.05, + p<.1.

Table 5: Pre Rationing Regressions

| | *Electricity Use Per Household (MWh)* | | | | *Real Wage* | *Elect. Price* | *Quantity Index* | *New App. Index* | *Old App. Index* |
|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| Treated Region | -.005 | -.024** | -.024** | -.009** | 126.5** | -.003 | -.115+ | -.046** | .014 |
| | (.009) | (.002) | (.002) | (.002) | (20.0) | (.004) | (.062) | (.009) | (.010) |
| Real Wage | | Yes | Yes | Yes | | | | | |
| Electricity Price | | | Yes | Yes | | | | | |
| App. Indices | | | | Yes | | | | | |
| *Mean in the control region* | .160 | | | | 673.4 | .104 | 0 | 0 | 0 |
| N | 312 | 312 | 312 | 312 | 24 | 24 | 44382 | 44382 | 44382 |

Note: Standard errors of RE estimation clustered by regions/state in parentheses. Regressions with constant. Appliances: fridge, freezer, AC, and TV. ** p<.01, * p<.05, + p<.1.

Table 6: Post Rationing Regressions

## 4.2 Electricity Consumption

Table 7 presents the main results from the paper. The relevant coefficients from estimating (1) using log of electricity consumption as dependent variable are presented on columns 1-4. We can see that, as a consequence of the restrictions imposed during the rationing, the electricity consumption on the southeast dropped around 30% relative to the consumption in the south, even when we control for income, electricity price and appliance inventory (quantity and vintage).

The most striking is the magnitude of the post rationed effects. We see that the 8-month restrictive policy led to a 20% reduction in monthly electricity consumption in the southeast relative to the south in the period from March 2002 until September 2010. This effect is very significant even when we control for prices and wages, or if we use different estimation procedures as discussed on the previous section. Interestingly, when we control for the inventory of appliances in order to take account of the extensive margin of consumption, as in column 4, we find that the rationing led to a long run reduction of more than 13% of electricity consumption. This suggests that a change on the intensive margin of consumption accounts for the biggest share the total consumption drop.

| | *Electricity Use Per Household* | | | | *Real Wage* | *Elect. Price* | *Quantity Index* | *New App. Index* | *Old App. Index* |
|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| During*Treated | -.315** | -.324** | -.326** | -.264** | .036 | .009 | .047 | -.100** | -.004 |
| | (.020) | (.029) | (.029) | (.027) | (.053) | (.095) | (.031) | (.018) | (.006) |
| Post*Treated | -.210** | -.204** | -.204** | -.133** | -.016 | .021 | -.023 | -.123** | .073** |
| | (.010) | (.014) | (.014) | (.014) | (.029) | (.052) | (.023) | (.017) | (.011) |
| Real Wage | | Yes | Yes | Yes | | | | | |
| Electricity Price | | | Yes | Yes | | | | | |
| App. Indices | | | | Yes | | | | | |
| N | 459 | 459 | 459 | 459 | 39 | 39 | 52805 | 52820 | 52820 |

Note: Variables in *log*s, except indexes, so coefficients can be interpreted as percent changes. Standard errors of RE estimation clustered by regions/state in parentheses. Regressions with constant, common trend, region/state and Post-Period FE. Observations: 459. ** p<.01, * p<.05, + p<.1. Appliances: fridge, freezer, AC, and TV.

Table 7: Difference in Difference Results

Columns 5-9 show how the other variables were affected by the rationing. We can see that the restrictions had no significant effect on wages[12] or electricity prices neither in the short run or in the long run.

[12] Since in section 4.1.1 we reject that wages were following a common trend in all areas, I perform a difference in difference estimation for wages allowing different trends as in Angrist and Pischke (2009).

I find no significant effect on the quantity of appliances neither in the short or in the long run. We see that appliances became less likely to be new in the rationed areas relative to the non-rationed ones, both in the short and long run. We see that just after the rationing (until mid 2003), appliances were as likely to have have being bought more than 5 year old, but that by 2008/2009 appliances became more likely to be old in the rationed areas. Although not significant under this specification, we see that the quantity of appliances reduced in the southeast in the long run.

These effects together suggest that people seems to have decelerated the expansion of the stock of appliances in the southeast, what contributes to the reduction in electricity consumption. However, as we see in column 4, this is not enough to explain the change in electricity use. For now, this interpretation is not crystal clear, I will address this point properly in a near future.

# 5 Discussion

I find evidence that a 8-month electricity rationing had persistent effects on household electricity consumption even 9 years later. Data suggests that the restrictions had no effects on real wages and electricity prices, but that it decelerated the acquisition of new appliances in the long run (not significantly). We still find a 13% drop in electricity consumption even when we control for all these variables. Given that the timing and the geographical allocation of the rationing were given by weather factors exogenous to the economy and households decisions, these evidences suggest that the temporary restrictions on electricity use brought households new consumption habits that are lasting for almost a decade for now.

This event provides evidence of a policy which lead to long run effects by maintaining the demand shifted by years. This finding is similar in spirit to Dupas (2010) and Bryan, Chowdhury and Mobarak (2011). If one understands that there are externalities around energy consumption - such as the pollution associated to it or, closer to the Brazilian case, the environmental costs involved in expanding the generation capacity -, one can also use this rationing to speculate about policies that seek long term effects in a public good setting, as sought by Kremer and Miguel (2007).

Fair, the policy analyzed here could not be compared with a nudge: it is a *stomp*. This difference, I believe, is the main contribution of this paper, since it could lead to very different policy implications. In some contexts, individuals are not fully aware of the marginal costs and benefits from their actions, and end up choosing sub-optimally. An example pointed by Allcott (2011b) is energy consumption. The author shows that, when making decisions regarding fuel consumption, people have biased and misleading perception of the actual cost of their choices, what lead to inefficient decisions. One could address this misinformations, or biases, simply by providing information. However, in some of these cases, informative policies may not be very effective, as in Bryan et al (2011), because information is very costly to be acquired by the people (due to complexity or lack of salience) or because individuals resist to experiment new behaviors, even when they are aware of their possibility.

In these settings, standard interventions that provide information or marginal incentives to individuals in order to let them to choose by themselves, would still lead to suboptimal choices. On the other hand, a policy that provides information to these individuals on what to do, and that enforces that they actually experience the optimum consumption for a certain period could be more effective to "educate" (or habituate) them with lasting effects. In short, to provide marginal incentives to an individual with a biased perception of the problem, will lead to new, but also biased, choices. By restricting their choice set to the optimum consumption options, these individuals would not have another option rather than to *just do it*, and "learn" the first best by experiencing.

An illustration to this point could be a comparison of the Brazilian experience with the Californian energy crisis in 2000. There, at the same time that the government made public appeals for the population to voluntarily reduce consumption, prices went up to accommodate the excess demand (Reiss and White, 2008). Households were not imposed any actions, they only faced higher prices and were given information to re-optimize their consumption. Under the biased or misleading story, even willing individuals could still respond to these incentives sub-optimally. As consequence, even with the higher prices not observed in Brazil, the short run effects observed there were less than a third of the ones we find in here, and no long run effect on consumption could be found there.

A limitation of this current paper is that I am unable to disentangle precisely which mechanisms were triggered by the restrictions. There are a few models that would lead to the same revealed preference and that I cannot rule out, such as rational addiction, reference-dependent preferences, default bias, or behavioral learning. Future work could use experiments to address these points.

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# A Extra Graphs and Tables

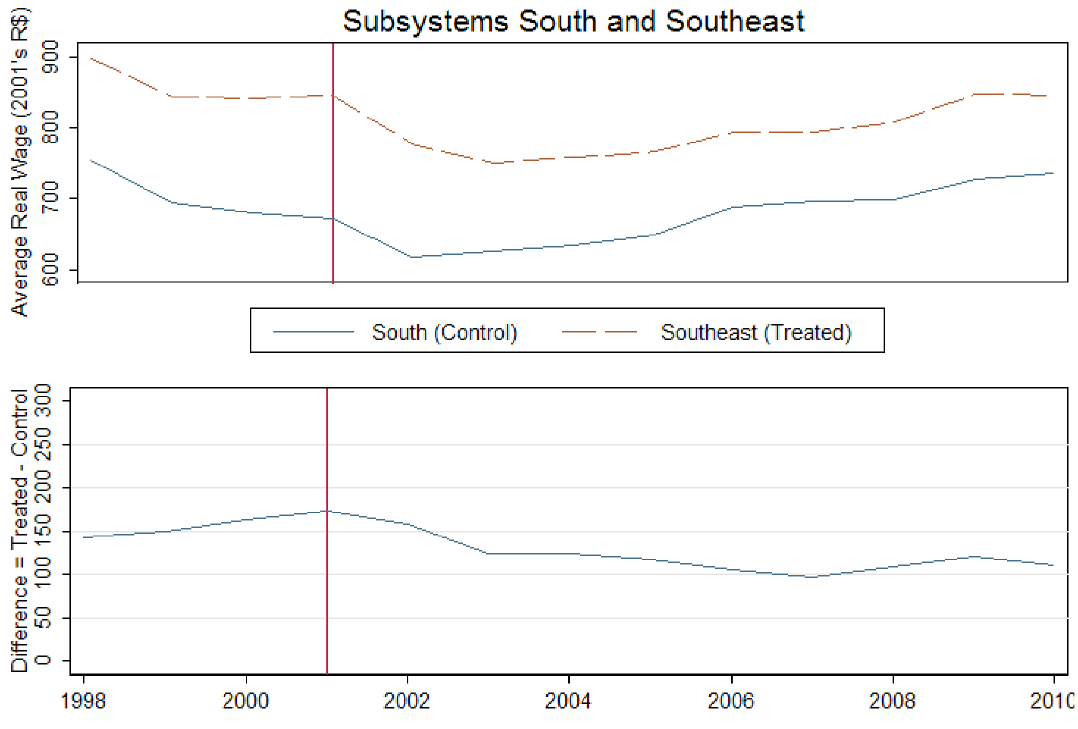


Figure 4: Average households real wage (2001's R$)

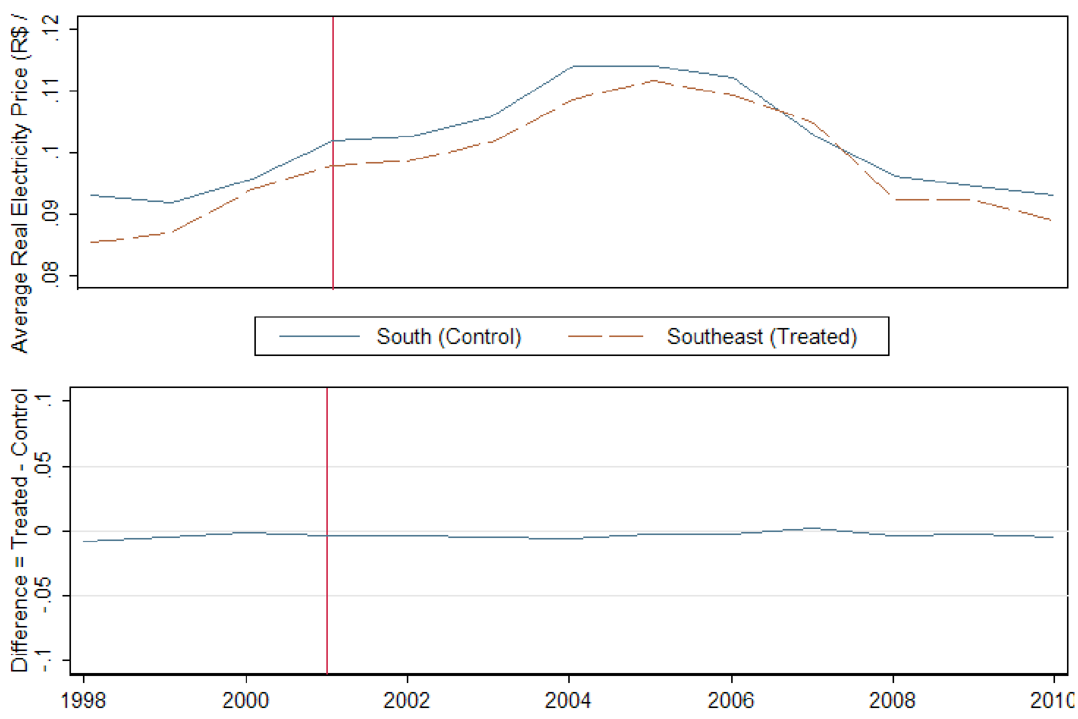


Figure 5: Average household electricity price (2001's R$)

## B Rationing Timeline

Mid-1999 Eletrobras makes studies to identify and contract emergency's generation units (mainly thermal power plants built on boats/platforms which could be connected to the grid on ports).

Feb-2000 The Priority Thermal Program (PPT) is created as the "unique solution" to a possible collapse of the system. This program, which become the focus of The Ministry of Mining and Energy (MME), identified 49 thermal plants and made special offers for those who started operation before 2003.

Early-2000 The Emergency Thermal Program, a reorientation of the PPT focusing on 15 main projects.

July-2000 In a meeting with the President and the Economic team, the minister of the MME, based on ONS's data, said: "considering the PPT, even if we observe an increase of demand bigger than the expected, we will not face energy supply and peak problems during 2000-2003 as long as the hydrological conditions [inflow energy] is above 85% of the long run average". The minister also stated that this condition would be satisfied with probability greater than 90%. (26/07/2000)

Late-2000 ANEEL established criteria for the competitive process of additional power offers (capacity auctions) and determine that the spot market should buy 2500 MW of extra capacity.

Dec-2000 ONS points a better scenario for 2001 than the 2000's one, with no collapse of the system.

Feb-2001 Due to the unfavorable rains in the previous two months, ONS points a radical change on 2001's forecast.

Mar-2001 ONS officially submit a requisition of a 20% load reduction to the federal Government (Nota Técnica ONS 019/2001).

Mar-2001 *First time ANEEL publicly address a possible imminent electricity shortage.* It proposes the Consumption Reduction and Supply Increase Plan (RECAO). This plan was abandoned shortly after, because it was said insufficient.

April-2001 PPT fails and MME starts designing the load reduction program.

June-2001 Household restrictions are implemented.

Some clarifications on these facts. The boat power plants, PPT and Capacity auctions failed.

The MME gave instructions to ONS and ANEEL to not publicly address the high default risks in order to avoid heated reactions from the society.

Until April 2001, ANEEL and MME were still trying to solve the problem by increasing generation, without alerting the risks to the society. The adoption of a restrictive policy to reduce demand was unexpected even to the central government. It is unlikely that most of the segments of the society anticipated that the restrictions would be implemented, mainly households, commercial consumers and small industries.