Can Rationing Affect Long Run Behavior? Evidence from Brazil

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Abstract

Although there is empirical evidence that economic problems may have multiple solutions, the feasibility of using temporary interventions to induce individuals to change behavior with sustainable effects is still contentious. I examine whether an temporary policy - electricity rationing - can affect long run household behavior. I look at evidence from a 8-month compulsory rationing imposed on Brazilian households' electricity use in 2001. I exploit the policy implementation in time and across regions as a quasi-experiment to test its long run impacts on households electricity consumption patterns. I find that the rationing program led to a persistent reduction in electricity use of 14% even ten years later. This long run effect is robust to different specifications. Unique household level microdata on appliance ownership and consumption habits show that the main source of persistence are changes in the utilization of electricity services, rather than the adoption of more energy-efficient appliances.
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1 Introduction

A whole class of economic models has multiple steady states. A common feature of these models is that temporary interventions can have long run effects by making individuals switch steady states. In policy terms this suggests that one do not need permanent interventions to tackle long run issues, such as the environmental consequences of fast growing developing countries. Therefore, it is important to understand both the feasibility of using temporary policies to address issues in a long horizon, and whether temporary policies do have long run impacts on individuals. This paper provides empirical evidence of a temporary intervention which had lasting impacts on households behavior.

Consistent with this class of models, empirical literature shows that small incentives, such as nudges, do affect individual behavior in the short run, but with limited long run effect.[1] On the other side, the persistent effect of historical episodes for current outcomes has been documented even when controlling for contemporary factors.[2] This suggests that specific events can place economic agents in different steady states.

To empirically assess if it is viable to induce agents to change steady states, one needs a big push. Although this debate goes as far as Rosenstein-Rodan (1943), the feasibility of using temporary interventions to generate such sustainable effects on individual behavior is still contentious as it lacks empirical evidence. While Kremer and Miguel (2007) are not optimistic about this possibility, Giné et al. (2010) and Dupas (2012) find that individuals do change health consumption patterns even one year later in response to temporary programs.[3]

This paper examines whether a temporary policy - electricity rationing - can affect long run household behavior. I look at evidence from a large rationing program in Brazil in 2001-2002, when households had to reduce electricity use by at least 20% for 8 months. I use the exogeneity afforded by the program's implementation in time and across locations to interpret this episode as a quasi-experiment. This episode is a good testing ground for a class of theories important for policy because the temporary restrictions on consumption were limited to certain regions due to a combination of weather condition and infrastructure constraints, generating a credible counter-

[1] For example, Charness and Gneezy (2009), Allcott and Mullainathan (2010), Acland and Levy (2011), Agarwal et al. (2011), Ferraro and Price (2011), Gneezy et al. (2011), John et al. (2011), and Haselhuhn et al. (2012).

[2] Bloom et al. (2003), Redding et al. (2010), Dell (2010), Acemoglu et al. (2012), Bleakley and Lin (2012).

[3] Kremer and Miguel (2007) find that replacing subsidies to deworming medicines with sustainable worm control measures were not effective to change long run behavior. Dupas (2012) argues that interventions can generate lasting impacts on behavior when it permits individuals to experience the full costs and benefits of their choices. She finds that a subsidy to antimalarial bednet increases adoption one year later. Giné et al. (2010) find that a six-month commitment product had a positive impact in smoke cessation even six months after its tenure.

factual, and it was fairly unexpected by households. I find evidence supporting the existence of multiple steady states in household electricity consumption, and, further, that the average household can reduce electricity use by 14% in the long run - ten years later - by switching to a less energy-intensive steady state.

I first present a simple theoretical framework where individual consumption optimization has multiple steady states. In theory, multiplicity could emerge from many mechanisms, such as habits, beliefs, social norms, reference-dependency, or learning (Naik and Moore 1996; Piketty 1995; Obstfeld 1984; Koszegi and Rabin 2006; Lindbeck 1997). For example, biased beliefs on the returns of investing in energy-efficiency can sustain different levels of energy efficiency, or social norms can make people change electricity use to fit a social group (Allcott 2011a, 2011b). The model presented illustrates this using a simple mechanism: intertemporal complementarity of consumption (Becker and Murphy 1988). In this model, the past level of electricity use affects the individual's current utility from consuming electricity services. For example, the more one uses electrical appliances in the past, the bigger the distress of not having access to its services presently.

My setting can be interpreted as a quasi-experiment. In the beginning of 2001 the electricity generation capacity of some states was severely undermined due to extreme low streamflow level in the rivers that serve the hydroelectric power plants of some regions. Since the Brazilian electricity system is partitioned, the government could not overcome the regional energy scarcity by reallocating electricity between regions. In order to prevent general blackouts, the government planned and implemented an emergency rationing program within a couple of months. In June 2001, households in the Southeast and Midwest were asked to reduce electricity consumption by 20% relative to their historical average for eight months. Households were subject to fines and the threat of supply interruption if they did not meet their target, and received bonuses for further energy saved. The rationing was a sudden change in government strategy, and as such was fairly unexpected by households.[4] After the end of the program in February 2002, electricity supply and prices went back to normal.

To estimate the rationing's impact on final average household electricity consumption, I use a panel of monthly average household electricity use and average price per utility company from 1991 to 2011, based on the utilities' records. This is administrative data from the Electricity Regulatory agency (ANEEL). To assess the mechanisms underlying the overall reduction in electricity use, I exploit unique household level microdata from a survey on appliance holdings and consumption

[4]Until May 2001, the government tried to reduce consumption with other measures, such as pure price schemes and increasing the generation capacity of thermal power plants. See quotes from newspapers in Appendix B.

habits of over 10 thousand families conducted by the Brazilian energy efficiency program PROCEL. I also use a second household level dataset with information on households appliances' inventory and vintage of more than 60 thousand families from the Brazilian Geography & Statistics Institute (IBGE).

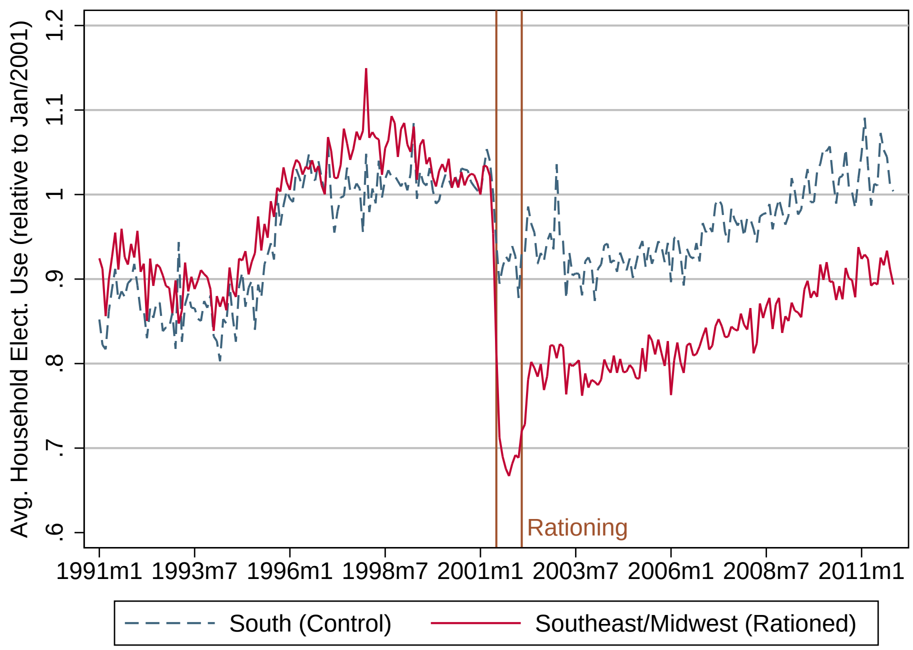

Figure 1: Rationing Effect on Average Household Electricity Use (1997-2010)

Notes. This graph presents the monthly average household electricity consumption in the South and Southeast/Midwest, normalized to levels of January 2001. The two vertical lines mark the rationing period. Administrative data from the Regulatory Agency ANEEL.

The main empirical strategy of this paper is a difference-in-differences specification using households in the non-rationed states in the South of Brazil as a control group for the rationed ones in the Southeast/Midwest. Under the assumption that households' electricity use in these regions would follow a common trend during the period studied, the regression estimations can be interpreted as the average treatment effect on the treated. I focus only on the most developed states of Brazil precisely to assure the plausibility of this assumption.[5]

[5]The Northeast was rationed as well. However, as discussed in Section 3, the Northern states were at a very different initial development stage, and experienced substantially different growth pattern during the 2000s. Identification assumptions do not hold for these regions. In particular, while more than 97% of households in the Southern states were connected to electricity in 2000, the share of households with electricity in the Northern states increased from around 80% in 2000 to around 95% ten year later. The main results still hold when pooling all states in the analysis.

Figure 1 presents the average household electricity use per month in the South (non-rationed) and in the Southeast/Midwest (rationed) from 1991 until the end of 2011, normalized at the levels of January 2001. We can see that the average electricity use in the two regions were following a similar trend in the ten years before the rationing. During the electricity crisis, marked with the two vertical lines, the average consumption of the rationed households dropped around 46 kWh (28%) relative the non-rationed ones. At the end of the rationing, consumption in the rationed region increased, however it never returned to the pre-rationing levels. From 2002 until 2010, the rationing caused a persistent reduction of 25 kWh (14%) in average monthly electricity use, and this long run effect is persist across time. These results are robust to different specifications, controls and sub-samples. This long run effect is equivalent to replacing three 60W incandescent light bulbs by fluorescent ones, or switching off a freezer for half of the month. The energy saved has been equivalent to 1.5 months-worth of electricity every year, for the last 10 years.

This persistent change gives some evidence that households settled into a new steady state with lower consumption levels. Microdata on consumption choices support the hypothesis that households actually changed the way they use electric appliances. Even three years after the rationing, I still find that rationed households maintained a lower level of freezer utilization, and lower electric shower temperature relative to the non-rationed ones. A back-of-envelope calculation suggests that these two actions could account for the long run electricity use reduction.

The reduction in electricity demand could also be caused by investments in energy-efficient appliances. However, microdata on appliance holdings suggests that purchases of energy-efficient durable goods did not play a major role in the long run effects. During the rationing, households seem to have substituted old refrigerators and postponed investment in new freezers and air conditioners. By 2008-2009, however, the average stock of appliance in the rationed areas became older relative to the non-rationed ones. To rationalize these findings, I present in Appendix A an extend version of the model with endogenous choice of appliances characteristic as Dubin and McFadden (1984). The empirical findings as a whole are consistent with it.

Taken together, this is evidence that households adopted a new consumption pattern during the rationing, shifting to a new stable steady state with lower electricity use due to a new consumption pattern as discussed initially.[6] The identification of long run impacts obviously faces important challenges, namely: (i) omitted variables that lead to endogeneity between the outcome variables and the rationing implementation, (ii) initial cross-sectional differences, and (iii) divergence in the time series and potential general equilibrium effects that may emerge over the years. I address each issue in turn in Section 4.

[6] Time series analysis indicates that there is a structural break in electricity demand in 2001 (Maciel et al. 2009).

This paper relates to different strands of the literature. First, it highlights the crucial importance of considering human behavior when designing energy and environmental policies. This is particularly related to the debate on the magnitude of a "energy efficiency gap" in society, defined as the difference between the available cost-effective, energy-efficient technologies and those actually adopted by consumers. McKinsey & Co. (2009) evaluates this gap to be worth over US$1.2 trillion in the US alone. However, these estimates are based on engineering analyzes of the performance of different technologies (Allcott and Greenstone, 2012). Evidence from a field experiment in Mexico shows that households can actually increase final electricity use when old appliances are replaced by new energy-efficient ones, because people increase utilization of these appliances (Davis et al., 2012). In the Brazilian case, technology did not play a major role in the long run, and most of the energy conservation seems to come from the utilization margin. This paper signals that we cannot discuss an "energy efficiency gap" without considering its behavioral counterpart.

This paper also forms part of a wider literature on the economics of energy conservation. Although it has been shown that demand response programs are a promising avenue for promoting energy conservation (Allcott and Mullainathan 2010), I am unaware of a program with lasting results of the same magnitude. Reiss and White (2008) found that the public appeals during the 2000 California energy crisis led to a short run reduction of 7% in household electricity use. Jessoe and Rapson (2012) examine a randomized controlled trial with 437 households in the USA,and find that a combination of price fluctuations and frequent feedback was effective to sustain conservation for at least 62 days after its tenure. Allcott and Rogers (2012) find that households who receive energy conservation information by mail for two years still maintain a 2% lower electricity use up to two years after the last letter.

The main contribution of this paper is to show empirically that one can use temporary interventions to promote sustained changes in consumption behavior and promote energy conservation.

The paper is organized as follows: I present the basic theoretical framework in Section 2. In Section 3 I describe the background and the data. In Section 4 I present the empirical methods and the results on electricity use. Section 5 examines the channels of persistence, consumption habits and stocks of appliances. Section 6 concludes.[7]

[7] Appendix A presents an extended version of the model accounting for investment in energy-efficient appliances. Appendix B presents the timeline with the events and evidence from media coverage, Appendix C describes the data cleaning, and Appendix D contains further empirical results.

2 Theoretical Framework

This section outlines the simplest possible model that illustrates how temporary restrictions can generate long run effects when multiple steady states exist. In this model, multiple steady states emerge as a consequence of intertemporal complementarity of consumption, as Becker and Murphy (1988). In order to derive further predictions, Appendix A presents an extended version of the model which explicitly accounts for strategic investment in appliances efficiency as a classic two stage discrete choice model. That is, I extend Dubin and McFadden (1984) into a dynamic model where intertemporal complementarity of consumption generates multiple steady states.

Suppose an infinitely lived individual, with exponential time discount factor $\beta < 1$. Every period the individual chooses ordinary consumption, c_t, and services from electricity, e_t. Assume preferences are such that electricity services consumed at different points in time are complements, as in Becker and Murphy (1988). That is, individual's current utility is represented by $u(c_t, e_t, s_t)$, where s_t captures the past electricity use relevant for current utility. This stock of past electricity use evolves according to $s_{t+1} = \delta s_t + e_t$, where $\delta < 1$ is depreciation. Assume that u is strictly concave in c and e, and that $u_c > 0$, $u_e > 0$ for all $c, e, s \geq 0$.

Assumption 1. *Current and past consumption of electricity services are complements, that is,* $u_{es} > 0$ *for all* $c, e, s \geq 0$.

This assumption introduces some path dependency on the utility derived from the utilization of electricity services. It means that the higher the past electricity utilization, the higher the marginal utility of current utilization. For example, the more one uses electrical appliances, the bigger the distress of not having access to their services. Assume individual is fully aware of her preferences, and maximizes utility taking into account that her current choices affects the marginal utility of the future consumption choices.

The individual has fixed income y in every period, we normalize the price of ordinary consumption to 1, and let the electricity price be p. Suppose no credit market.[8] Therefore, the individual solves the following dynamic optimization problem:

$$
\begin{aligned}
V(s_t) = \max_{c_t, e_t} u(c_t, e_t, s_t) + \beta V(s_{t+1}) \\
s.t.\ c_t + pe_t \leq y \\
s_{t+1} = \delta s_t + e_t.
\end{aligned}
\tag{1}
$$

[8]Results are not affected if we assume perfect credit market with interest rate $R^{-1} = \beta$.

One can write this problem as a function of e_t and s_{t+1} by substituting the budget constraint into the utility function. Let $w(e_t, s_t) \equiv u(y - pe_t, e_t, s_t)$. The policy correspondence which describes the optimal consumption path is defined by $s^*(s) \equiv \{s' | V(s) = w(s' - \delta s, s) + \beta V(s')\}$. We call $\bar{s}$ a steady state if $\bar{s} \in s^*(\bar{s})$. Denote s^c a critical level if the optimal path diverges around s^c. I call a steady state stable if it is not a critical level.

Proposition 1. *Problem* (1) *has at least one stable steady state; any solution path for the stock of past consumption, s_t, monotonically approaches a stable steady state; and there is exactly one critical level between any two consecutive stable steady states.*

Proof. Proposition 1 in Orphanides and Zervos (1994), page 70. □

The Rationing (Dynamics)

The rationing in this setting can be interpreted as a temporary restriction on electricity use, such that the individual solves a constrained optimization problem. Denote s_0 the individual stock of electricity services at the beginning of the rationing, and τ the duration of the rationing. Let $e^*(s)$ be the optimal unconstrained electricity use when the stock of past consumption is s. Therefore, during the rationing the individual maximizes utility by solving problem (1) with the additional restrictions

$$e_t \leq \bar{e} < e^*(s_0) \text{ for all } t \in [0, \tau].$$

As a consequence of the restrictions, the stock of electricity utilization must decrease during the rationing. Figure 2 provides a graphical illustration of the dynamics, with electricity use on the vertical axis and stock of consumption on the horizontal axis. Suppose an individual is initially at the steady state $s_0 = s_H^*$. During the rationing she is forced to consume below $\bar{e}$, the horizontal, reducing stock of consumption. If by the end of the rationing the stock of consumption $s_{\tau+1}$ is smaller than a critical point $s^c < s_0$, then the individual will enter a new optimal path that will converge to a new stable steady state with smaller electricity consumption s_L^*. If the stock of consumption does not decrease below any critical level, consumption will converge back to the original level after the rationing.

Prediction 1. *Households reduce utilization during the rationing.*

Prediction 2. *After the rationing, households whose stock of consumption falls below a critical point enter a new optimal path that converges to a steady state with lower utilization of electricity services.*

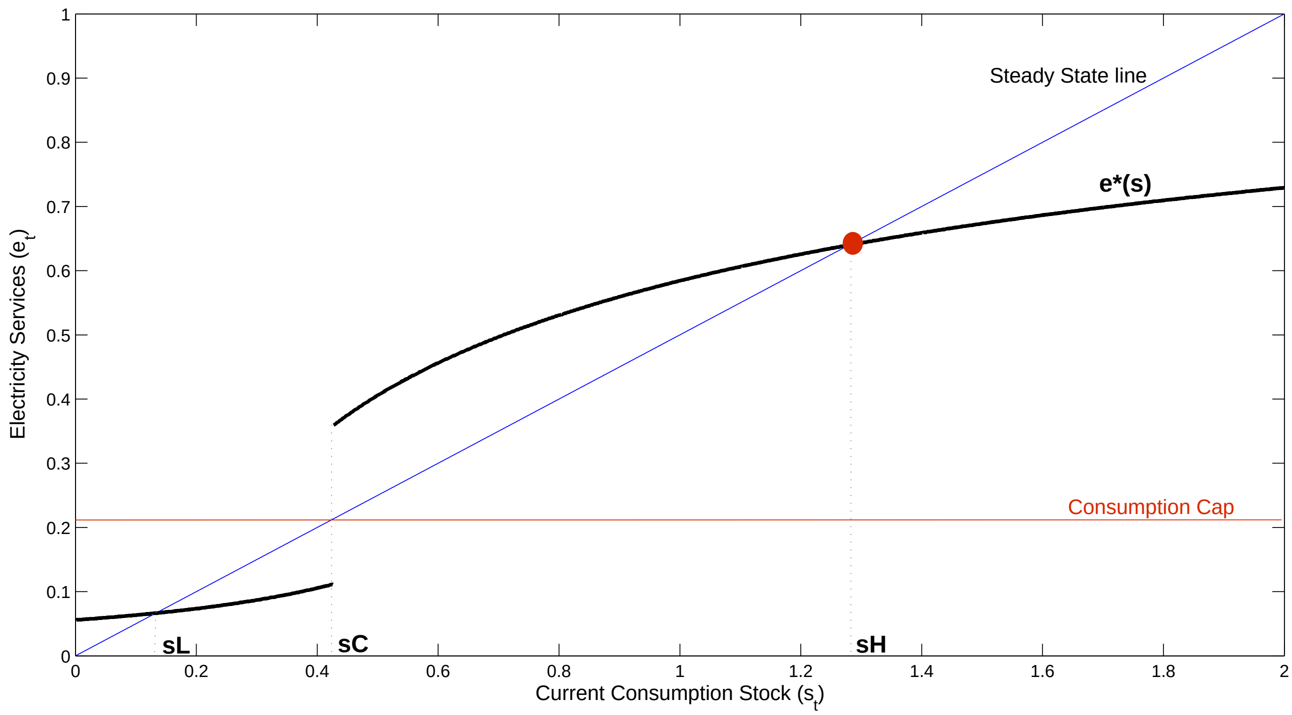

Figure 2: Illustration of Rationing Dynamics in an Optimization Problem with Multiple Steady States

Notes. Example using $u(c, e, s) = \mu \ln c + (1 - \mu) \ln e + \gamma s e$, with $\mu = 0.95$, $\gamma = 1.1$, $\beta = 0.9$, $\delta = 0.5$, and $y = p = 1$. The two stable steady states are sL and sH, and sC is a critical point.

In sum, if the optimization problem of recurrent consumption decisions has multiple steady states, rationing can generate long run effects by making individuals switch steady states. I assumed one possible source of multiplicity of steady states, the intertemporal complementarity of consumption. The rationing dynamics would be similar in the whole class of models that generate multiplicity of steady states.

The source of multiplicity, however, is crucial when deriving welfare conclusions regarding the rationing and its dynamics. In this model, individual is fully rational and take into account that their current consumption choices affects his future utility. Therefore, the rationing necessarily creates a net welfare loss to this individual. However, steady states could be Pareto-ranked depending on specific assumptions of the model, for example if electricity use involves externalities or internalities. In fact, there is supporting evidence for both, being through the social costs from power generation (Stern 2007; IEA 2011; Nordhaus 2011) or individual misperceptions regarding energy use (Allcott and Mullainathan 2010; Allcott 2011b). Thus, there are aggregate gains from shifting consumption to steady states with smaller energy use. The main issue at evaluating the net benefit of the rationing is that the transition costs have different interpretations according to each model. Since I cannot unveil the actual mechanism underlining the multiplicity of steady states, I cannot derive a clear welfare conclusion of this policy, and I leave this for future work.

Just as a benchmark comparison, consider introducing a temporary marginal incentive, such as a marginal price change. All steady states levels under the temporary incentives will change continuously and will involve smaller electricity use. Once incentives are removed, the stock of consumption will be near the original steady state level and individuals will converge back to their original consumption levels. However, if the price change is sufficiently big then individuals may switch to new stable steady states as in the constrained problem above.

The extended version of the model presented in Appendix A, which accounts for investment in durables, has analogous findings. Any persistent change in appliances acquisition are due to switching steady states with different utilization of electricity services. The extended model is closer to the energy and durables literature, and contains predictions on how specific appliances should be affected by the rationing.

3 Background and Data

In this section I explain the Brazilian electricity rationing, describe the data used, and provide summary statistics.

The Brazilian electricity system relies almost exclusively on hydrological resources. From 1998 to 2000, 94% of the electricity used in the country was generated by hydroelectric power plants (ONS 2003). The national electricity grid is divided into four subsystems: South (S), Southeast/Midwest (SE), Northeast (NE), and North (N). The subsystems are connected with transmission lines which support a limited exchange between regions.[9] I restrict attention to the period after the privatization of the Brazilian electricity sector and the creation of the Regulatory Agency (ANEEL) in 1996. Under the new regulatory framework, utility companies receive concessions to supply energy in delimited areas, and face no competition. The Regulatory Agency defines the electricity price.[10]

Since the electricity system in the North and the Northeast was in an early development stage, I focus only on the regions of Brazil in which electricity coverage was already high before the

[9]The national grid is controlled by the National System Operator (ONS), which coordinates the electricity generation and transmission.

[10]There are two tariff bands, the regular (B1) and a subsidized rate for households who receive transfers from the government.

rationing: the South, Southeast and Midwest.[11] Table 1 presents summary statistics of these regions.

The rationing was an emergency program designed to avoid the collapse of two subsystems in a period when electricity supply would not meet the demand. The official report about the rationing's causes concludes that *"no demand factor contributed to the unbalancing of the system and the collapse in 2001"* (Kelman, 2001).[12]

As this report concludes, supply factors were exclusively responsible for the 2001 collapse. Figure 3 shows the reservoirs' levels as a percentage of their maximum capacity for the subsystems Southeast/Midwest and South, from 1996 to 2010. The first half of the year is the wet season of subsystem Southeast/Midwest. It is when power plants' reservoirs are filled to guarantee the electricity supply later in the year. It happened that the stream-flow level of rivers in this subsystem was extremely low in the first months of 2001, recording some of the lowest levels of the historical series. As a consequence, the reservoirs in the Southeast/Midwest reached critical levels, and in March 2001 ONS asked the federal government for an intervention in order to reduce demand by 20% in this region.[13]

The government initially tried to boost thermal generation with the Priority Thermal Program. However, it was not successful and, in April 2001, the load reduction program started to be designed. In the middle of May the government announced in the national media that restrictions on household electricity use would be applied starting in June 2001. It was said that the restrictions would initially last 6 months, but could be extended. The restrictions lasted two months longer and were withdrawn in February 2002. I present a timeline with the events and evidence from media coverage in Appendix B. As can be seen in Figure 3, the generation capacity in the South

[11] The electricity grid in the southern states was already developed in 2000, with more that 97% of electricity penetration among households. In the northern regions, electricity covered only around 80% of households. Further, in the beginning of this century, the federal government launched the program *Luz Para Todos* (Light For Everyone) which aims to bring electricity to every household in the country. The northern states were the most affected by this policy, and electricity coverage in these states increased to near 95% in less than a decade. This substantially changes the household sample composition, because a significant share of consumers in these states were not directly affected by the rationing.

[12] Table A1 presents the realized electricity demand as a fraction of the forecasted demand from the Decennial Energy Plan 1997-2007 (PDE, 1997) for each year and region. From 1998 and 2000, the realized demand was below the expected one, even when considering households market only. That is, there was no unexpected growth of electricity demand in the years prior 2001. Further, the installed generation capacity would support the forecasted demand under regular natural conditions.

[13] Notice that in the beginning of 2000, the reservoirs levels in the Southeast/Midwest were in a critical level similar to 2001, and the reservoirs in the South were below average as well. However, these regions experienced above average stream-flow in 2000 what saved the system from a collapse in that year. If the stream-flow that the Southeast/Midwest experienced in early 2001 had happened in early 2000, both the Southeast/Midwest and the South would have been rationed in 2000 (Kelman 2001).

was secure, and therefore these states were not rationed.

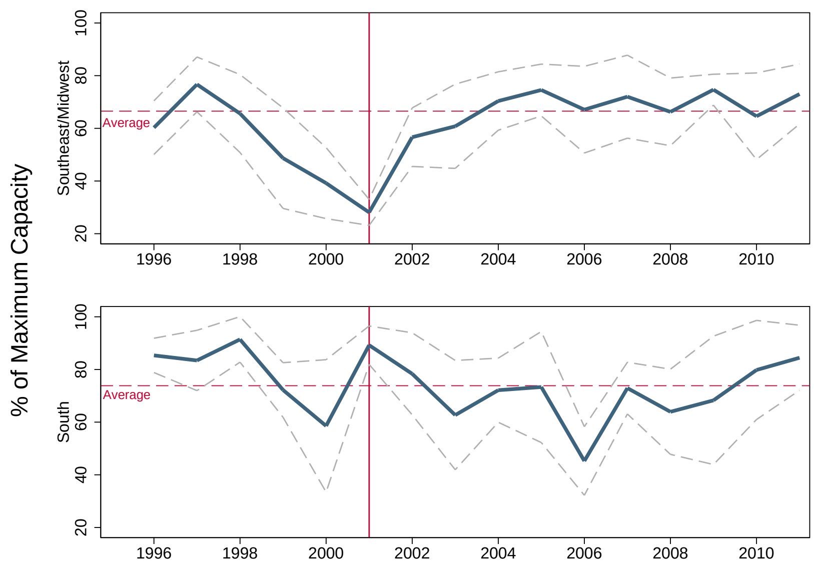

Figure 3: Annual Average Water Level in the Reservoir as Percentage of its Maximum Capacity (1996-2011)

Notes. The solid line is the annual average water level in the reservoirs as a percentage of their maximum capacity for each subsystem and year. The dash lines mark an area within one standard deviation from the mean. Source: National System Operator (ONS).

The restrictions and incentive structure imposed on households' electricity use were based on an individual target equal to 80% of the average consumption on the previous year using a 3-month rolling window.[14] Households with monthly average consumption above 100 kWh[15] who failed to reach their target would pay fines and could have their electricity cut for up to six days. Those with monthly average consumption below 100 kWh were not subject to these penalties. All households received bonuses of up to R$2 for each R$1 saved below their target. Also, a non-linear tariff was temporarily implemented, with a 50% overcharge on the electricity consumed above 200 kWh and below 500 kWh, and a 200% overcharge to any consumption above 500kWh.

It is important to highlight that the government also issued a national information campaign through its energy efficiency program, PROCEL/Eletrobrás. Both the campaign and the rationing itself received massive coverage in the national media, reaching even the non-rationed states. In an extra effort to conserve electricity, energy-efficient appliances, such as fluorescent light bulbs, received tax exemption from the federal government.

[14]I.e., in June 2001, each household should consume at most 80% of his own average consumption on May, June and July 2000.

[15]These households represented more than 70% of the units, and more than 85% of total consumption in the Southeast.

3.1 Data

Next I describe the three main data sets and other sources of information used in the paper. Table 2 presents a summary with the three main datasets used, and Appendix B presents details on the data cleaning and a complete list and description of all variables used.

3.1.1 Electricity Data (ANEEL)

Electricity data is administrative data from the Brazilian Electricity Regulatory Agency (ANEEL), with the monthly records of each utility company, from January 1997 until December 2010. It contains the number of households connected to the utility company, the amount of electricity sold to them, and the total revenue from the electricity sold to households. Average electricity use per household in each utility is calculated by dividing the total electricity sold to households by the number of households connected. The prices exerted by each utility company are defined by the Electricity Regulatory Agency (ANEEL), and there are two tariff bands for residential consumers: the regular and a subsidized social tariff for low income households. Since there is no retrospective disaggregated data on electricity consumption of households paying the social tariff, I cannot use the objective prices to calculate the average electricity price. Therefore, I calculate the average electricity price exerted by each utility by dividing the total revenue by the amount of electricity sold to households.

3.1.2 Habits of Energy Use (PPH)

The government's energy efficiency program PROCEL, from the national electricity company Eletrobrás, conducts a detailed survey every 7 years to assess the characteristics and utilization habits of household electricity consumers. The Appliances and Habit of Use Survey (*Pesquisa de Posse de Equipamentos e Hábitos de Uso,* PPH) is designed by PROCEL with the assistance of academic institutions. Households in different cities are visited by an interviewer, as is done in a Census survey. The questionnaire includes both objective questions on household characteristics and habits, as well as qualitative questions. Although most of the information is self-reported, the interviewers were supposed to check some of the information, for example, the number of lamps in the living room, and the characteristics of the main refrigerator and electric shower.

I use the micro data of the two last surveys, one conducted between July 1998 and June 1999, and the last one conducted between July 2004 and June 2005. The data contains information on 14,254 households from the 10 utility companies surveyed in both years. To the best of my knowledge, this is the first time this survey is being used in the social sciences. The main variables used in the paper are: the number of appliances permanently in use, electric shower's thermostat regulation, and the adoption of ten energy-saving measures.[16] I aggregate these ten energy-saving actions into one index following Katz, Kling and Liebman (2004).[17]

I also use this dataset to assess the quantity of lamps (per type) and electric showers.

3.1.3 Appliances Holdings (POF)

Microdata used to assess appliance holdings are from the Household Budget Survey (POF), a national survey conducted by the Brazilian Geography & Statistics Institute (IBGE) who is also responsible for the National Census. One of the main objectives of this survey is assessing households' expenses and consumption baskets to support the calculation of IBGE's consumer price index (INPC). I use the household level microdata from the three last surveys, which are 1996/1997, 2002/2003 and 2008/2009. All surveys were conducted between July of the base year and June of the following year. Unfortunately, the 1996/1997 survey covered only the main metropolitan areas of each region, while the two subsequent surveys covered rural areas as well. I use data from all areas, although results do not change if I restrict the sample to the urban areas only.

The data contains characteristics from around 61,342 households in eleven different states. The microdata contains the quantity of different types of appliances owned by the households and the year these appliances were bought. It does not have details about the model of these appliances, or whether the appliance were bought new or second-hand. To capture changes in recent acquisition patterns, I create a dummy variable, New, which is equal to one if the appliance was bought within 2 years. Note that an appliance that was less than two years old in 2002/2003 was bought exactly around the rationing period, so this variable will be used to capture unusual appliance acquisition during the rationing. In sum, the three dependent variables used are the appliance's quantity, age and New dummy.

Finally, there is a relevant difference between the sampling of this survey and the sampling of the two datasets presented so far. The official records from the Electricity Regulatory Agency

[16] Namely: (1) Switch off the lamps when leave the room for more than 30 minutes; (2) Do not open the fridge/freezer door fully; (3) Do not storing warm food in the fridge/freezer; (4) Do not dry clothes behind the fridge/freezer; (5) Verify the condition of fridge/freezer's rubber seals regularly; (6) Reduce shower time when using an electric shower; (7) Adjust the shower thermostat according to the ambient temperature; (8) Use washing machine in full load; (9) Accumulate clothes to iron; (10) Switch off the TV when not watching.

[17] These Indices 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 imputed at the group mean.

(ANEEL), and the Appliances and Habit of Use Survey (PPH) only contain households regularly connected to electricity. The Household Budget Survey (POF), however, aims to be representative of households as a whole, including those who have irregular connections to electricity. Consequently, some households in POF own electrical appliances, but claim to have no expenses on electricity and not to own a generator. Since these households who do not pay for electricity were not subject to the rationing's incentives, I exclude them from the main specification of the paper.

3.1.4 Remaining Data

Nominal wages and number of workers in formal employment come from the RAIS dataset (Brazilian Ministry of Labor), aggregated by year-state. The consumer price index is INPC produced by IBGE, which contain monthly indices for the main metropolitan areas in each region. Unfortunately, Brazil does not have a periodic consumer price index for rural areas. I compute prices and wages in real terms by dividing nominal variables by the INPC index. Microdata on appliances prices from metropolitan areas is from IBRE/FGV. Data on electricity generation, rivers' conditions and level of reservoirs are from the National System Operator (ONS), the body responsible for running the electricity generation and transmission systems in Brazil. Remaining weather data is from the National Meteorology Institute (INMET), which are microdata with daily measures for each of 45 meteorological stations in the region. The remaining information is from the National Census 2000.

4 Empirical Method and Main Results

The main identification strategy to estimate the short and long run effects of the rationing is a difference-in-differences specification using the non-rationed states from the South of Brazil as a control group for the rationed ones in the Southeast/Midwest. As mentioned in the introduction, any causal inference of this estimation hinges on a few assumptions. Before listing and assessing the plausibility of them, I present the basic regression form:

$$Y_{it} = \alpha + \beta_D During_t * Ration_i + \beta_P Post_t * Ration_i + \gamma_t + \gamma_i + \gamma X_{it} + \epsilon_{it} \tag{2}$$

where Y_{it} is the dependent variable of utility i at year-month t. $During_t$ and $Post_t$ are dummies equal to one for months during and after the rationing respectively, $Ration_i$ is a dummy equal to one if the utility was rationed, γ_i and γ_t are utility and year-month fixed effects, and X_{it} is a vector of covariates - for example, real wage, and real electricity price. I do not impose any structure on the errors correlation over time and cluster errors at the utility company level, i, as Bertrand et al. (2004).

The parameters of interest are β_D and β_P. The estimates of β_D can be interpreted as the program's average short run effect on the treated[18] if there are no omitted variables associated with both the rationing allocation (timing and across locations) and with households' potential electricity use [*Assumption 1*], and if the evolution of household electricity use were following a common trend in the South and the Southeast/Midwest [*Assumption 2*].[19] The estimates of β_P capture the program's average long run effect on the treated if, in addition to these two assumptions, there would have been no divergence in the time series of electricity use and covariates over the years following the rationing [*Assumption 3*].

Section 3 provides clear evidence supporting *Assumption 1.* The official diagnosis of the energy crisis concludes that supply factors aggravated by severe streamflow levels triggered the rationing, and states: "the realized electricity consumption growth [from 1997 and 2000] corresponded to the growth forecast and had no influence on the generation crisis" (Kelman 2001, pg. 5).

We can see in Table 1 that the South and Southeast/Midwest regions are not identical in levels. However, these are the most developed regions of Brazil, with the Southeast being the richest region with the two largest cities. Thus, despite some differences, average household electricity use is statistically equivalent in the two regions prior 2001 when controlling for income and prices. Regarding *Assumption 2*, as shown in Figure 1, average electricity use in the South and Southeast/Midwest were following roughly the same evolution since 1991. Although I reject that household electricity consumption in the two regions were following a common trend since the privatization (from 1997 to 2001), this difference is really small as apparent in Figure 1. I address this issue by allowing different trends in one specification.

Assumption 3 is the key challenge of assessing long run impacts of any policy: maintaining a meaningful counterfactual for several years. In order to overcome this issue, I follow the historical literature and use different regression specifications controlling for a series of time-varying covariates. Figure A2 plots the evolution over time of electricity prices and wages in these regions. Table A3 presents a simple difference-in-differences estimation to illustrate their evolution over the period. I find no difference on the evolution of all variables, except that temperature seems to

[18] It is worthy to highlight that, since the rationing program implemented a series of measures, the treatment captured here is the rationing program faced by households net the effects of pure information provision and subsidies, which were implemented in the South as well.

[19] See Manski and Pepper (2012) for a full discussion on identification.

have increased $0.5^o c$ in the South in the last decade, which would bias the estimates downwards.[20]

Table A4 presents the same difference-in-differences estimation to illustrate evolution of covariates in the states from the North and Northeast of Brazil. One cannot reject the hypothesis that, during the years studied, more households were connected to electricity in the Northeast than in the North, and that the share of households paying for electricity increased, the number of employed workers increased, and the average wage decreased in the Northeast relative the North. In other words, the North and Northeast were at a different development stage, and followed a different evolution, than the rest of Brazil. Since the Northern states fail to satisfy Assumptions 2 and 3, I discard them along the analysis.

Further, I do not find evidence of relevant migration across the regions[21], or that households evaded rationing by spreading usage across more meters or irregular connections.[22]

This evidence, together with the robustness checks support the plausibility of the identification strategy. Further issues with the identification will be discussed accordingly in Section 5.

4.1 Main Results

Table 2 presents the estimates of the equation (2), using different sets of controls and samples. During the rationing, households in the Southeast/Midwest reduced consumption by 46.7 kWh/month relative to the ones in the South region in the same period, a reduction of 28%. This is the equivalent to the electricity used by a freezer or a medium sized refrigerator in a month. We can see as well that the long run effect is about half of this value in all specifications. That is, households took some temporary measures to reduce electricity consumption during the rationing, however part of these new consumption pattern remained after the crisis.

As previously discussed, the evolution of covariates such as wages and prices could affect electricity demand over the years, especially because general equilibrium effects could emerge. To deal with this issue I control for real electricity prices, real wages and temperature as shown in columns 2

[20] Temperature in the Southeast/Midwest virtually did not change relative to the late nineties. Since higher temperatures are associated with higher electricity demand, the South may have increased electricity consumption relative the initial trend after 2002. Thus, the difference-in-differences results would underestimate the actual effect of the rationing. I would find similar results if I count the number of days above $32^o c$ in these regions.

[21] Oliveira and Oliveira (2011) documents that the Southeast experienced a net out-migration in the periods from 2000 and 2004 and from 2000 and 2009. The magnitude of these numbers are no bigger than 0.2% of the Southeast population, and less than 0.5% of the South population.

[22] Data from the Regulatory Agency shows no difference in the evolution of the number of meters in the two regions, I find no difference in the number of households irregularly connected to electricity in POF data set, and the PPH data shows no difference in the number of households with home business.

to 4. I also control for a cubic polynomial of these variables, in column 6, and results are largely unaffected. To address the issue of non-parallel trends, I run one specification with a specific time trend for rationed and non-rationed states, in column 5. Rationing impacts get even bigger in this case, and I cannot reject that the coefficient of the two trends are equal.

A further concern is that since households in both regions are heterogeneous, they could respond differently to covariates. That is, even if prices and wages evolved similarly in the two regions after the rationing, households could have different elasticities.[23] The specification in column 7 addresses this point by permitting utility-specific price and wage elasticities. I control for the interaction utility dummy-price and utility dummy-wage. This is the specification under which the rationing had the smaller short and long run effects. Even so, I find that long run electricity use decreased 22.6 kWh/month. Column 8's specification uses all controls together. I cannot reject the equality of the long run effects under all these eight specifications.

We can see in Figure 4 the evolution of the rationing effect over time in Figure 4. It presents the coefficients of the rationing effect on each six month period, from the second half of 1997 until the end of 2010, using the specification in Table 2, column (3).[24] As previously argued, consumption in the Southeast was decreasing relative the South, but we cannot observe strong anticipatory effects in the first half of 2001. Further, we can see that the long run effect stabilize two years after the rationing.

Columns 9 and 10 address potential issues with the sample of the data. Column 9 presents the rationing effects when construct a "synthetic treatment" group analogous to Abadie and Gardeazabal (2003). That is, base on observable characteristics of utility companies, I find which of the rationed ones were more similar to the non-rationed ones from the South before the rationing, and then restrict the sample to these utility companies only.[25] Column 10 presents results pooling all 63 utility companies in the country, including the ones in the North and Northeast. In both cases, the estimated effects are not severely affected.

As a further robustness check I perform placebo estimations using nine different dependent vari-

[23]For example, if households in the Southeast were more price elastic than those in the South, a common price increase in both regions would lead to different consumption changes. Although this would imply that the electricity demand from wealthier households is more price elastic, it is theoretically plausible.

[24]Formally, it plots the coefficients of the interaction year-semester and rationed region dummies, β_s, in the equation below

$$Y_{it} = \alpha + \sum_s (\beta_s Semester_t * Ration_i) + \gamma_i + \gamma_t + \gamma X_{it} + \epsilon_{it}$$

where Y_{it} is the log of average household electricity use in utility i, in year-month t. Further, γ_i and γ_t are utility, year-month fixed effects, and X_{it} is a vector of controls with real electricity price and real wage. I combined the 8 months from the rationing as the second half of 2001.

[25]EXPLAIN

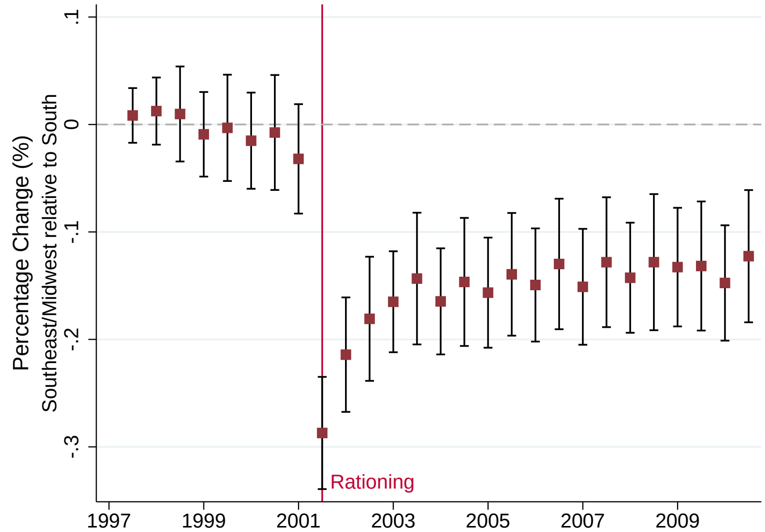

Figure 4: Rationing Effect on Average Household Electricity Use (1997-2010)

Notes. Each dot is the estimated difference-in-differences of the rationing effect on the rationed households in each six-month period. It represents the coefficient β_s estimated from the equation in footnote 4. Dependent variable is log of average household electricity use, per month and utility company. Controls are utility and year-month fixed effects, real electricity price and real wage. The vertical bars represent a 95% confidence interval, where standard errors are clustered by utility (44 clusters). Source: Electricity Regulatory Agency (ANEEL) and RAIS (Ministry of Labor).

ables, such as electricity prices, households connected to electricity, wages and temperature. Results are presented in Table A3. I find that the rationing had statistically significant effect only in one of these nine variables: temperature. As discussed in the begging of this section, data suggests that the average temperature in the South (the non-rationed states) increased by $0.5^o c$ after the rationing relative to the temperature in the Southeast/Midwest.

Therefore, there is strong evidence that the temporary demand response program did change final household electricity demand in the long run, or at least for a 10 year period. Even controlling for a wide range of covariates, one cannot neglect the rationing impact. Also, this effect stabilized within two years and is flat since 2003, supporting the multiple steady states story.

5 Channels of Persistence

In this section I use microdata go inside the households and shed light on the channels supporting the long run reduction in electricity use. There are two non-competing stories which could be underlying the long run energy conservation. Households could have both changed how they use electrical appliances, or invested in more energy efficient appliances. It is important to disentangle the intensive and extensive margin of consumption because they relate to different economic mechanisms, and would have different policy interpretation.

The first channel says that for given prices, income and technology, households use appliances differently. In this case, we can bring to mind economic models where the individual optimization problem has multiple steady states. For example, models with habits, beliefs, social norms, or consumption complementarity as the one presented in Section 2. In the first part of this section I present direct evidence from household level microdata that individuals' appliances utilization were affected by the rationing.

At the same time, the rationing could have affected households' investment in energy efficiency. Since durables depreciate over time, the acquisition of a new refrigerator which consumes less electricity would have lasting impacts on final household energy demand. In this case, households marginally indifferent between replacing an old appliance by a new one would have had extra incentives to take action during the rationing. To illustrate this point, in Appendix A I present an extend version of the model from Section 2 where the choice of appliances characteristics is endogenous. In the second part of this section I investigate the contribution of technology to the long run energy conservation. I exploit household level microdata[26] which gives me snapshots of the quantity and vintage of households' appliances holdings in different periods. Evidence suggest that the composition of appliances did not change substantially in the long run.

I restrict attention to the five appliances which represent 85% of average household electricity use (PROCEL, 2007): electric showers, refrigerators, freezers, air conditioners, and lamps. I use the same identification strategy described in the previous section, performing the following difference-in-differences estimation:

$$Y_{hit} = \alpha + \sum_{t>0} \beta_t dYear_t * Ration_i + \gamma_t + \gamma_i + \gamma X_{hit} + \epsilon_{hit} \tag{3}$$

where Y_{hit} is the dependent variable of household h, in region i and year t. Region i can be utility company or state according to the dataset. $dYear_t$ are dummies for years, $Ration_i$ is a dummy equal to one if the region i was rationed, γ_i and γ_t are region and year fixed effects, and X_{hit} is

[26] Note that I am not investigating appliances' optimal life cycle. To precisely assess if households attitudes towards technology adoption changed in the period, one would need data with the flow of new appliances bought by households and the flow of the destination of the old appliances (i.e., if displaced or sold on the second hand market). Unfortunately, this data does not exist. I use stock data which only provides indirect evidence on how appliances' life cycle. However, the data used does provide direct evidence on the average energy efficiency of households' inventory of appliances in different points in time.

a vector of controls with household characteristics. I do not impose any structure on the errors correlation over time and cluster errors by region i.

There is one caveat for identification in this section. By the nature of the data, I cannot explicitly test the common trend hypothesis for all dependent variables. To attenuate this issue, I control for many households' characteristics which may be correlated with different trends.

5.1 Electricity Consumption Habits

This subsection presents results from the Appliances and Habits of Use Survey (PPH) 1998/1999 and 2004/2005. Table 3 presents the descriptive statistics of appliance inventory and habits of electricity utilization of the average household in the two regions. As we can see, the three electricity services which account for most of average household electricity use are electric shower (water heating), refrigerators and lighting. We can see that in 1998/1999 the average household in the Southeast/Midwest had a higher utilization of all services than the Southerner one. The only exception is lighting. We also see that households in the Southeast/Midwest used to adopt less energy-saving measures than those in the South.

Table 4 presents the estimates of a difference-in-differences regression (3) for each of these variables controlling for utility company, and year fixed effects, income, squared income, number of household members, build up area, and dummies for rich neighborhood and for proximity to slums ("favelas"). As indicated in the table, I present results in units of kWh/month whenever it is possible.[27]

The use of electric shower to heat water corresponds to more than a fifth of average electricity use. The regression results presented in column 1 suggests that the rationing affected the regulation of electric showers thermostat generating savings of around 15 kWh per month.[28] We can see also in column 3 that households in the Southeast/Midwest reduced freezer utilization due to the rationing, saving around 10 kWh per month on average. In other words, households who own a freezer in the Southeast/Midwest became 17% less likely to have it permanently switched on relative to those in the South. These two variables by itself could account for all long run energy conservation.

I do not find that the rationing had a statistically significant impact on any other variable, such as the utilization of refrigerators, lighting or air conditioners as shown in columns 4 to 7. However, all

[27] I convert each variable to kWh/month by calculating: [Number of appliances per type/regulation] * [Average electricity consumption per type/regulation].

[28] The thermostat of an electric shower can be switched off or regulated at "Low Power" (*Modo Verao*) or "High Power" (*Modo Inverno*). A shower regulated at Low Power consumes on average 30% less electricity than when one set at High Power.

point estimates are negative. As shown in column 8, the rationing had no impact on the probability of households adopting any of ten energy-saving measures, as described in Section 3.1.2.

Table A6 in the Appendix present the rationing effect on each of these 10 measures, using a logit estimation. I find a statistically significant increase in the adoption of four of these ten measures, all the four relate to refrigerator, freezer or electric shower utilization. For example, "reduce shower time when using an electric shower" in column 6, and "adjust the shower thermostat according to the ambient temperature" in column 7. I find no statistically significant effect on the remaining six measures.

These findings suggest that households changed the electricity services regularly used, even controlling for a series of individual characteristics. This is further direct evidence that the rationing did make households switch steady states. Results are largely unaffected when using different specifications. Further, qualitative questions asked to rationed households in 2004/2005 are coherent with these findings, as shown in Table A8.

5.2 Electrical Appliances Holdings

This section shows that a newer and more energy-efficient stock of appliances cannot account for the long run reduced electricity demand. In order to assess if the rationing affected the average stock of appliances, I use microdata from the Household Budget Survey (POF) 1996/1997, 2002/2003 and 2008/2009, and Appliances and Habit of Use Survey (PPH) 1998/1999 and 2004/2005. I characterize the inventory of appliances with three variables: the quantity of appliances owned, the age of each appliance, and the dummy New which is equal to one for appliances bought within the last two years.

The first part of Table 5 presents the estimates of the difference-in-differences regression (3) using POF data controlling for state fixed effects, year fixed effects, income, squared income, number of bedrooms, number of household members, and a dummy for rural regions. These are sample weighted regressions using only those households who pay for electricity, that is, those regularly connected to electricity as described in Section 3.1.3.

Analogously to the habits of use data, in column 4 we can see that the rationing reduced the average number of freezers in the Southeast/Midwest relative to the South. The short run effects in freezers would be responsible for the conservation of more than 4 kWh per month. Although one cannot reject that the equality of the coefficients capturing the short and long run effects on the quantity of freezers, I find that the long run effect is not statistically significant. Columns 1 and 7 also show no effect on the quantity of refrigerators and air conditioners both in the short and long run.

Although the quantity of appliances was not affected, the rationing could influenced the households decision of replacing old appliances by more efficient ones. Columns 2 and 3 provides evidence that households in the Southeast strategically substituted refrigerators during the rationing. In 2002/2003, the rationing did not affect the number of refrigerators owned (column 1), but it did reduced the average age of refrigerators (column 2), and increased by 2.5% the share of households who bought a refrigerator in the previous two years (column 3). However, this effect dissipates over time and I find no effect on the stock - quantity and vintage - of this appliance in 2008/2009.

Columns 6 and 9 suggest that the share of households who bought freezers or air conditioners in the previous two years became smaller both in the short and long run. We see in columns 8 that the average air conditioner became relatively older in the Southeast Midwest. This is indirect evidence that the rationing reduced the replacement rate of these appliances in the Southeast/Midwest. These results are robust under different specifications and restricting to sub-samples, such as to metropolitan areas.

Further, these results are consistent with the standard model of appliance acquisition and utilization (Dubin and McFadden 1984) when extended to allow for multiplicity of steady states, as described in Appendix A. In this model, appliances that provide price-elastic electricity services are less likely to be utilized during the rationing, reducing the incentives to invest in new appliances in the short run.[29] In the long run, price-elastic services will be the most affected when individuals converge to a new steady state with less services from electricity. A smaller utilization of electricity services reduces the incentives to invest in newer and more energy-efficient technologies, leading to long run effects on the stock of appliances.

The POF dataset does not contain information on lamps and electric showers. I use data from the PPH to examine the stock of these appliances. As shown in the continuation of Table 5, I find no significant change in the number of lamps or electric showers in the Southeast/Midwest relative to the South. Note that when we compare these results with the ones in Table 4, we see that it is the intensive margin of utilization which is driving the reduction in the electricity consumption of electric showers.

In sum, the microdata suggests that a newer and more efficient stock of appliances cannot account for the long run reduction in electricity use. Therefore, changes in the intensive margin of consumption must be supporting the persistent reduction on electricity use. Table A8 also provides

[29] In the Brazilian case, the rationing started during winter, when air conditioners are more dispensable.

qualitative evidence from the PPH survey supporting this idea.

6 Conclusion

Both economic theory and empirical evidence recognize that economic problems may have multiple steady states. However, the feasibility of using temporary interventions to induce individuals to switch steady states with sustainable effects is still being discussed by the empirical literature and policy makers.

This paper contributes to this discussion by providing evidence from a large electricity rationing program in Brazil in 2001-2002. The main contribution of this paper is to show that one can use a temporary intervention as a big push to promote sustained changes in consumption behavior. I observe that households can switch to steady states with smaller energy consumption in response to a temporary demand response program. The long run effect observed is stable over time, and the energy saved has been equivalent to 1.5 months-worth of electricity every year, for the last 10 years, and counting.

A caveat of this paper is that I cannot empirically disentangle which precise mechanisms generate the multiplicity of steady states sustaining the long run effects. Understanding the precise model driving the results is crucial in order to estimate the welfare cost of the transition between steady states. Not less important, the picture emerging from the household level microdata show that the temporary rationing had lasting impact on people changing behavior and appliances utilization, rather than an increased adoption of energy-efficient technology.

From an energy perspective, this is important because it shows that quantity restriction affect behavior. A key difference between this paper and the literature that assesses the persistence of historical events is that the policy studied here could be replicated. And a difference between this policy and most of the demand response programs in the literature is that it was not a nudge, or a small incentives given to households. It was a nation size intervention which account for general equilibrium effects and potential complementarity between different underlying mechanisms, such as price, information, social norms, and habits.

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Table 1: Summary Statistics (Base Year 2000)

	South (1)	Southeast/Midwest (2)	North (3)	Northeast (4)
Panel A. Electricity				
Share of households with electricity (%)	97.9	98.5	79.5	86.6
Number of households with electricity (millions)	6.1	22.4	1.9	9.2
Number of utility companies	17	27	8	11
Average household electricity use (kWh/month)	178.1 (5.9)	201.6 (6.2)	169.9 (5.9)	113.2 (5.4)
Average household electricity price (R$/kWh)	.157 (.009)	.162 (.005)	.153 (.004)	.148 (.004)
Share of households paying for electricity	.92 (.01)	.90 (.01)	.87 (.01)	.79 (.01)
Panel B. Macro Covariates				
Consumer Price Index (base 2001)	.89 (.01)	.90 (.00)	.92 (.01)	.94 (.01)
Average wage (R$)	654.1	809.9	650.9	523.4
Average temperature (^{o}c)	19.2	23.2	26.5	25.0
Panel C. Households' Characteristics				
Average household size	3.5 (1.6)	3.6 (1.8)	4.5 (2.4)	4.3 (2.3)
Share of households with refrigerators/freezers	.91 (.29)	.89 (.31)	.62 (.48)	.59 (.49)
Share of households with air conditioners	.07 (.26)	.07 (.26)	.09 (.29)	.04 (.44)

Notes. This table displays the descriptive statistics from the regions in columns. Share of households paying for electricity are from 1996/1997, all other statistics refer to 2000. Standard deviation in parentheses. The statistics in *Panel A* are from the Electricity Regulatory Agency (ANEEL) balance sheet, which is disaggregated at month-utility company level (528 observations in the year); except the share of households connected to electricity from 2000 National Census; and the share of households paying for electricity from the Household Budget Survey 1996/1997 (POF/IBGE) microdata calculated using sampling weights. *Panel B*'s statistics come from three different sources: Consumer Price Index from INPC/IBGE, at month-metropolitan area level; wages from the Ministry of Labor's register (RAIS) at year-sate level; and temperature from the National Meteorology Institute (INMET). The statistics in *Panel C* are from the 2000 National Census (IBGE) microdata.

Table 2: Estimation Results

	Dependent Variable: Average Household Electricity Use (kWh/month)									
	Regions South, Southeast, and Midwest								Synthetic Treatement	All Brazil
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
During*Rationing, β_D	-46.696***	-45.978***	-45.126***	-45.801***	-47.306***	-45.103***	-43.630***	-47.295***	-39.851***	-38.068***
	(2.831)	(2.836)	(2.656)	(2.858)	(3.074)	(2.648)	(2.726)	(3.082)	(2.612)	(3.297)
Post*Rationing, β_P	-25.683***	-25.539***	-24.982***	-25.316***	-31.655***	-24.716***	-22.624***	-31.885***	-21.690***	-17.576***
	(2.259)	(2.315)	(2.239)	(2.284)	(2.993)	(2.391)	(2.703)	(3.845)	(2.484)	(2.523)
Real Elect. Price	.	✓	✓	✓	✓	✓	✓	✓	.	.
Real Wage	.	.	✓	✓	✓	✓	✓	✓	.	.
Temperature	.	.	.	✓	.	.	.	✓	.	.
Different Trends	.	.	.	.	✓	.	.	✓	.	.
Cubic Polynomial	.	.	.	.	.	✓	.	✓	.	.
Covariates-Utility Interacted.		.	.	.	.	.	✓	✓	.	.
Observations	7686	7686	7202	6606	7202	7202	7202	6606	5908	10902
Utilities, i (cluster level)	44	44	44	44	44	44	44	44	29	63
Months, t	179	179	168	168	168	168	168	168	179	179
R-squared	0.883	0.885	0.887	0.889	0.888	0.889	0.900	0.905	0.843	0.921

Notes. This table displays the difference-in-differences estimates of the rationing effects on the rationed households during and post the intervention, captured by β_D and β_P from equation (2). Each column corresponds to a different regression using the specifications indicated in the rows. The unit of the coefficients is kWh/month. *Sample* in columns 1 to 8 comprises all the 44 utility companies from the subsystems South and Southeast/Midwest, monthly from January 1997 until December 2010. The Sample in column 9 constitutes 29 utility companies from the South and Southeast/Midwest selected using a procedure analogous to "synthetic control" from Abadie and Gardeazabal (2003), detailed in Appendix C1. The sample in Column 10 constitutes the utility companies in the whole Brazil, excluding Pará where the rationing had a particular timming and target. All regressions are weighted by the number of households connected to each utility company. *Standard errors* are clustered by utility company. *Controls.* All regressions with constant, year-month and utility company fixed effects. "Different Trends" includes a specific time trend for the rationed region. "Cubic terms" stands for a cubic polynomial of real prices and wages. "Covariates-Utility Interacted" stands for the interaction RealPrice*Utility and RealWage*Utilities, which aim to capture a utility-specific price and wage sensitivity. *Source.* Average household electricity use and nominal average electricity price from the Electricity Regulatory Agency (ANEEL) records, which is at month-utility company level. Nominal wage from the Ministry of Labor's register (RAIS) at year-sate level. I compute prices and wages in real terms by dividing nominal variables by the Consumer Price Index (INPC/IBGE), at state-month level. Temperature is from the National Meteorology Institute (INMET). A Levin–Lin–Chu Test rejects the hypotheses that these variables are non-stationary series. *** p<.01, ** p<.05, * p<.1.

Table 3: Baseline Average Household Appliance Inventory and Utilization Habits

	Year 1998/1999				Year 2004/2005			
	South		Southeast/Midwest		South		Southeast/Midwest	
	Raw	kWh/month	Raw	kWh/month	Raw	kWh/month	Raw	kWh/month
Electric Showers								
Quantity	.96 (.01)	39.85	.97 (.01)	46.43	1.14 (.02)	47.79	1.12 (.01)	41.96
Thermostat Low Power	.74 (.01)		.46 (.01)		.18 (.02)		.72 (.01)	
Thermostat High Power	.06 (.01)		.40 (.01)		.76 (.02)		.21 (.01)	
Refrigerators								
Quantity	.96 (.01)		1.00 (.00)		1.03 (.01)		1.01 (.00)	
Quantity Always On	.94 (.01)	37.21	.97 (.00)	38.57	1.00 (.01)	39.45	.98 (.13)	38.81
Age	8.11 (.14)		7.67 (.08)		7.98 (.19)		7.69 (.09)	
Freezers								
Quantity	.25 (.01)		.20 (.01)		.42 (.02)		.19 (.01)	
Quantity Always On	.22 (.01)	11.73	.18 (.01)	9.87	.36 (.02)	19.44	.13 (.01)	6.88
Age	5.93 (.20)		5.24 (.12)		6.81 (.25)		6.68 (.18)	
Air Conditioners								
Quantity	.03 (.00)		.10 (.00)		.27 (.02)		.09 (.01)	
Quantity Frequently Used	.01 (.00)	1.41	.04 (.00)	7.74	.03 (.00)	6.28	.01 (.00)	1.8
Age	5.57 (.75)		5.94 (.23)		6.77 (.39)		5.59 (.26)	
Incandescent Light Bulbs								
Quantity	8.14 (.12)		7.3 (.06)		4.59 (.20)		5.36 (.10)	
Quantity Frequently Used	5.02 (.11)	45.18	2.83 (.05)	25.46	2.49 (.12)	22.41	2.06 (.04)	18.52
Fluorescent Light Bulbs								
Quantity	1.02 (.05)		1.16 (.04)		4.63 (.17)		3.29 (.10)	
Quantity Frequently Used	.81 (.04)	1.83	.74 (.03)	1.66	2.53 (.12)	5.68	1.63 (.06)	3.68
Adopt Energy-saving Measures								
Share of Households	.85 (.01)		.79 (.01)		.94 (.01)		.92 (.01)	
Total Estimated Electricity Use		137.2		129.7		141.1		111.7
Realized Average Electricity Use		176.4		210.3		156		160.5

Notes. This table displays the summary statistics of households in the regions in the columns from the Appliances and Habits of Use Survey (PPH) 1998/1999 and 2004/2005, conducted by the Brazilian energy efficiency program PROCEL. Columns labelled *Raw* present the average sample level in the units of each variable. Columns labelled *kWh/month* present the imputed monthly electricity use of each variable, converted using estimates from PROCEL presented in Table A5. Quantity is the number of appliances owned. "Always On" is the number of appliances permanently switched on. "Frequently Used" is the number of appliances used more than four times a week. "Adoption of Energy-Saving Measures" is the adoption of actions to save energy, described in Section 3.1. Standard deviation in parentheses. "Realized Average Electricity Use" is from the Regulatory Agency ANEEL. Dataset does not contain sample weights.

Table 4: Results on Consumption Habits

	Electric Shower Thermostat (kWh)	Appliances Always Switched On		Appliances Frequently Used				Adoption of Energy-Saving Measures (Mg. Eff.)
		Fridge (kWh)	Freezer (kWh)	AC (kWh)	Lamps All (kWh)	Lamps Incandescent (kWh)	Lamps Fluorescent (kWh)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Rationing Effect in 2005 (β_{05})	-15.807**	-1.455	-10.433**	-7.582	-4.783	-2.467	-2.316	.022
	(6.474)	(1.729)	(3.862)	(4.171)	(13.610)	(15.206)	(1.824)	(.039)
2005 Dummy(γ_{05})	15.207**	3.046	10.710**	6.137	3.956	-0.627	4.583**	.109***
	(5.298)	(1.796)	(3.735)	(3.572)	(12.849)	(14.569)	(1.728)	(.023)
Sample Mean	45.8	38.3	9.0	4.1	29.2	26.9	2.3	.85
Estimation Method	OLS	OLS	OLS	OLS	OLS	OLS	OLS	Logit
Utilities i (cluster level)	10	10	10	10	10	10	10	10
Observations	11071	11070	11068	11071	11071	11071	11071	10589
R-squared	.386	.082	.166	.067	.278	.247	.118	.034

Notes. This table displays the difference-in-differences estimates of the rationing effects on different proxies for consumption habits, from equation (4) in Section 5. Each column corresponds to a regression of a different dependent variable and appliance. Columns 1 to 7 present the coefficients of OLS estimation expressed in units of kWh/month. Column 8 present the marginal effects of logit estimation. Household level microdata is from the Appliances and Habits of Use Survey (PPH) 1998/1999 and 2004/2005 conducted by the Brazilian energy efficiency program PROCEL. *Sample* comprises ten utility companies from the subsystems South and Southeast/Midwest. All regressions contain utility company fixed effects, year fixed effects, income, squared income, number of household members, build up area, and dummies for rich neighborhood and for proximity to "favelas". "Electric shower thermostat" in column 1 is the total electricity use of electric showers considering adjustments on the thermostat regulation which can be Off, Low Power or High Power. In columns 2-3, "Appliances Always Switched On" stand for the number of appliances that are in permanent use. "Appliances Frequently Used" in columns 4-7 correspond to the number of AC and light bulbs used more than four times a week. "Energy-Saving Measures" in column 8 corresponds to the adoption of any energy-saving measures, decried in Section 3.1. Standard errors in parentheses are clustered by utility company (10 clusters). Dataset does not contain sample weights. ***p<.01, **p<.05, *p<.1.

Table 5: Results on Appliances Holdings

	Refrigerator			Freezer			AC		
	Quantity (kWh)	Age (Years)	New (Mg. Eff.)	Quantity (kWh)	Age (Years)	New (Mg. Eff.)	Quantity (kWh)	Age (Years)	New (Mg. Eff.)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Rationing Effect in 2002 (β_{02})	0.316	-1.174***	.025**	-4.152*	-.450	-.009***	9.606	2.099***	-.004*
	(0.800)	(.149)	(.012)	(2.268)	(.486)	(.003)	(8.767)	(.547)	(.002)
Rationing Effect in 2008 (β_{08})	0.289	-.072	.009	-3.806	-.422	-.006***	-0.716	1.737***	-.005***
	(0.655)	(.099)	(.010)	(2.216)	(.424)	(.001)	(6.067)	(.304)	(.001)
2002 Dummy (γ_{02})	-0.646*	-.370**	-.028**	-1.400	1.782***	-.007***	-22.520*	-1.759***	.000
	(0.354)	(.139)	(.011)	(2.273)	(.163)	(.001)	(10.320)	(.537)	(.002)
2008 Dummy (γ_{08})	-0.007	-1.636***	-.003	-4.983**	2.790***	-.008***	-18.331*	-2.185***	.002***
	(0.537)	(.064)	(.008)	(2.212)	(.425)	(.001)	(9.995)	(.317)	(.001)
Sample Mean	39.7	6.8	.087	11.0	7.4	.012	23.7	6.2	.009
Estimation Method	OLS	OLS	Logit	OLS	OLS	Logit	OLS	OLS	Logit
States, i (cluster level)	11	11	11	11	11	11	11	11	11
Observations	52805	48733	52805	52805	11279	52805	52805	4356	52805
R-squared	.048	.025	.005	.154	.069	.073	.204	.044	.128

Notes. This table displays the difference-in-differences estimates of the rationing effects on the average stock of appliances, from equation (4) in Section 5. Each column corresponds to the results of the regression of a different dependent variable and appliance, measured in the units indicated in the columns. Household level microdata is from the Household Budget Survey 1996/1997, 2002/2003 and 2008/2009 (POF/IBGE). *Sample* comprises all the eleven states from the subsystems South and Southeast/Midwest. *Quantity* means the number of appliances in the domicile converted to its electricity use (kWh/month). *Age* is the number of years since the appliance was bought. Regressions of these two dependent variables are estimated using OLS. *New* is a dummy variable equal to 1 if an appliance was bought less than two years ago, and zero otherwise. Regressions of New use logit estimation, and I report the marginal effects. Note that an appliance observed in 2002/2003 with less than two years old was bought exactly in 2001 or 2002. Therefore, the rationing effects in 2002 in columns 3, 6 and 9 captures the rationing impact on the share of households who bought appliances in the period. All regressions *controls* for state fixed effects, year fixed effects, income, squared income, number of household members, and dummy for rural regions. Standard errors in parentheses are clustered by state (11 clusters). All regressions use sampling weights. ***p<.01, ** p<.05, * p<.1.

Table 5: Results on Appliances Holdings (Continued)

	Dependent Variable: Appliance Quantity			
	Electric Shower (kWh)	Lamps All (kWh)	Lamps Incandescent (kWh)	Lamps Fluorescent (kWh)
	(1)	(2)	(3)	(4)
Rationing Effect in 2005 (β_{05})	0.018	1.085	3.266	-2.181
	(3.913)	(12.092)	(14.659)	(2.657)
2005 Dummy(γ_{05})	7.695**	-6.905	-14.274	7.370**
	(2.951)	(11.938)	(14.428)	(2.499)
Sample Mean	46.5	64.3	60.5	3.9
Estimation	OLS	OLS	OLS	OLS
Utilities i (cluster level)	10	10	10	10
Observations	11071	11071	11071	11071
R-squared	.234	.391	.337	.171

Notes. This table displays the difference-in-differences estimates of the rationing effects on the average stock of appliances, from equation (4) in Section 5. Each column corresponds to a regression of a different dependent appliance, and present the coefficients of OLS estimation expressed in units of kWh/month. Household level microdata is from the Appliances and Habits of Use Survey (PPH) 1998/1999 and 2004/2005 conducted by the Brazilian energy efficiency program PROCEL. *Sample* comprises ten utility companies from the subsystems South and Southeast/Midwest. *Quantity* is number of appliances in the domicile converted in electricity use (kWh/month) *without* accounting for change in utilization pattern. All regressions contain utility company, and year fixed effects, income, squared income, number of household members, build up area, and dummies for rich neighborhood and for proximity to "favelas". Standard errors in parentheses are clustered by utility company (10 clusters). Dataset does not contain sample weights. ***p<.01, **p<.05, *p<.1.

A Extended Theoretical Framework with Durables Acquisition

Suppose a two-stage decision process. In the first stage, individual chooses between I appliances portfolios, each with characteristics Θ_i. One of these characteristics is energy efficiency, and for simplicity, let the I portfolios be ordered in increasing energy efficiency, i.e., $i = I$ is the most energy-efficient portfolio. The rental price of appliance portfolio i is r_i in annualized terms. The first stage optimization problem can be represented by

$$W(s_t) = \max_{i \in 1,2,...,I} \{V(\Theta_1, s_t), ..., V(\Theta_I, s_t)\}$$

where $V(\Theta_i, s_t)$ is the conditional indirect utility of choosing appliance portfolio Θ_i when individual has stock of electricity use s_t, as described in Section 2.

In the second stage, the individual chooses consumption and utilization of services from electricity conditional on the durable portfolio chosen in the first stage Θ_i. That is, this second stage is similar to the model in Section 2, with the additional feature that services from electricity, e_t, is a function of the appliances portfolio and the actual electricity use. Let E_t be actual electricity use, the services from electricity is given by $e_t = f(E_t|\Theta_i)$, where f is the production function of services from electricity given appliances Θ_i and electricity consumption E_t. Therefore, the individual optimization problem is

$$W(s_t) = \max_{i \in 1,2,...,I} \{V(\Theta_1, s_t), ..., V(\Theta_I, s_t)\} \tag{4}$$

$$V(\Theta_i, s_t) = \max_{c_t, e_t} u(c_t, e_t, s_t) + \beta W(s_{t+1}) \tag{5}$$

$$s.t.\ c_t + pe_t \leq y - r_i$$

$$s_{t+1} = \delta s_t + e_t$$

$$e_t = f(E_t|\Theta_i).$$

This problem can be greatly simplified by assuming that there is no joint production and that the production function has constant returns to scale (Pollak and Wachter 1975). In this case, the marginal cost of producing e is constant and the indirect utility function can be written as a standard consumption optimization with budget constraint $c_t + \pi(p|\Theta_i) e_t \leq y - r_i$, where $\pi(p|\Theta_i)$ is the marginal cost of producing one extra unit of electricity service, e_t.

Proposition 1 in Section 2 characterizes the solution of the second stage problem (3) for a given portfolio choice Θ_i. We argued that that for each appliance portfolio Θ_i, utilization monotonically converges to a stable steady state. Since more energy-efficient portfolios have lower marginal cost of electricity services, $\pi\left(p|\Theta_i\right)$, the individual consumes more services from electricity, assuming the income effect of electricity prices to be sufficiently small. Therefore, more energy-efficient portfolios are associated with steady states with higher utilization of services from electricity. Therefore, for any initial stock of electricity use s_t, the optimal appliance choice and utilization of electricity services will monotonically converge to the steady state of one of the appliances portfolios Θ_i.

The Rationing (Dynamics)

The rationing in this setting is a period when the individual is restricted to use less raw electricity, E_t, than his initial optimal choice $E^*_{i^*}$. That is, individual optimization problem has an extra constraint $E_t \leq \bar{E} < E^*_{i^*}$, that can be written as a restriction on the utilization of appliance portfolios. During the rationing, for any appliance portfolio i, the optimal services from electricity is $\min\left\{e^*\left(p, y - r_i|\Theta_i\right); f(\bar{E}|\Theta_i)\right\}$.

As discussed in Davis, Fuchs, and Gertler (2012), the optimal appliance portfolio choice during the rationing, if one invest in efficiency or not in more efficient appliances, depends on the price elasticity of the electricity service of each appliance. Durables that provide inelastic services which can't be substituted by less energy-intensive services, such as basic food refrigeration, would be substituted by more energy-efficient ones in order to maintain the service level. On the other hand, appliances that provide elastic services which can be substituted by less-energy intensive technologies, such as air conditioners, would be less utilized and, consequently, would receive less investments. This yields two additional predictions.

Prediction 3. *During the rationing, the average stock of appliances that provide inelastic (elastic) services tend to become more (less) energy-efficient.*

The results from Section 5 are consistent with this prediction. The evidence suggests that during the rationing households substituted old refrigerators by new and more efficient ones, at the same time that they switched off freezers and utilized less air conditioners postponing the acquisition of these appliances.

Once the rationing is over, incentives regarding durables are back to normal, and the individual is back to the unconstrained problem (4) and (5). Therefore, any long run effects will emerge through new steady states on consumption of electricity services. In particular, appliances portfolios can be affected in two directions. An individual who invest in energy-efficiency during the rationing would be able to sustain a higher utilization level and her consumption stock would be less likely to fall below a critical level and converge to a lower steady state. Those who postpone investments in appliances and reduce utilization during the rationing, would use even less services from electricity and would be more likely switch steady states.

Prediction 4. *After the rationing, individual enters an optimal path that monotonically converge to a steady state with weakly lower consumption of services from electricity, and weakly less energy-efficient appliances portfolio.*

An individual who join a new optimal path and converges to a steady state with lower services utilization will have less incentive to invest in appliances' efficiency. Her new optimal portfolio choice will be weakly less energy-efficient than her original one. Evidence from freezers presented in Section 5 are consistent with this prediction.

B Rationing Timeline

Mid-1999 Eletrobrás makes studies to identify and contract emergency generation units (mainly thermal power plants built on boats or platforms).

Feb-2000 The Ministry of Mining and Energy (MME) creates the Priority Thermal Program (PPT) to increase the generation capacity of thermal power plants as the "unique solution" to a possible collapse of the system.[30]

Early-2000 The Priority Thermal Program becomes the Emergency Thermal Program.

July-2000 In a meeting with the President and the Economic team, the minister of the MME dismissed the chances of any energy crisis during 2000-2003.[31]

Dec-2000 ONS points a better scenario for 2001 than the 2000's one with no energy crisis.

Feb-2001 Hydrological conditions reaches 70% of the long run average, and ONS radically change the forecast for 2001.

[30]In a technical report published in 1999 (ONS-DPP 059/1999), ONS presented simulations of hydrological scenarios for 2000 based on the actual reserve levels in 30 November of 1999. The report concludes that the reservoir levels in some regions would hit zero in 13% of these scenarios.

[31]Based on documents from the National System Operator (ONS), the minister stated: "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 is above 85% of the long run average".

Mar-2001 ONS officially request the federal government a 20% load reduction (ONS-DPP 019/2001).

Mar-2001 *First time the regulatory agency (ANEEL) publicly address a possible imminent electricity shortage.* It proposes the Consumption Reduction and Supply Increase Plan (RECAO), which was abandoned shortly after.

April-2001 PPT fails and MME starts designing the load reduction program.[32]

May-2001 Government announces a six months rationing to be implemented in June.[33]

June-2001 Household restrictions are implemented.

Feb-2002 Household restrictions are withdraw.[34]

C Data Cleaning

D Statistical Appendix

D.1 Qualitative Variables

Tables A7 and A8 tabulates the responses from qualitative questions contained in the Appliances and Habits of Use (PPH) survey 2004/2005. Table A4 gives some intuition on how the rationing affected the life quality of households from both regions, and in which extent people substituted incandescent light bulbs by fluorescent ones as a consequence of the rationing. Only 21% of households in the Southeast/Midwest answered that the rationing was an uncomfortable period, and only 8% said they felt very uncomfortable. Most surprisingly, 43% of the rationed households declared the rationing had not impact on their life quality. This table also suggests that people from both regions did learn how to use electricity more efficiently.

[32]"Plan to hold expenditure on electricity" aims to reduce consumption in three regions with 25 measures. In case these measures are not effective it is possible that these regions will have blackouts in June. (Folha de São Paulo, Front page, A1, 06/04/2001). "Plan to avoid rationing failed", only 3 of the planned measures were implemented. (Folha de São Paulo, B7, 05/05/2001)

[33]Folha de São Paulo: "Government is not decided between regular supply interruptions or higher tariffs" (Front page, A1, 15/05/2001); "Plan will affect households with electricity bill above R$29" (Front page, A1, 18/05/2001); "Government imposes 'super tariffs' and will cut electricity of those who don't save" (Front page, A1, 19/05/2001); "Households should avoid storing food at home and do groceries more often" (B10, 29/05/2001); "Subsidies do not reduce light bulb's prices" (B7, 01/06/2001).

[34]"Rain brings reliefs to reservoirs" (Folha de São Paulo, B1, 03/01/2002).

Table A5 presents results on what households from the Southeast/Midwest did with their appliances after the rationing was over.[35] We see that a significant share of households started using less all appliances. Unfortunately, these questions were not asked to the households in the South.

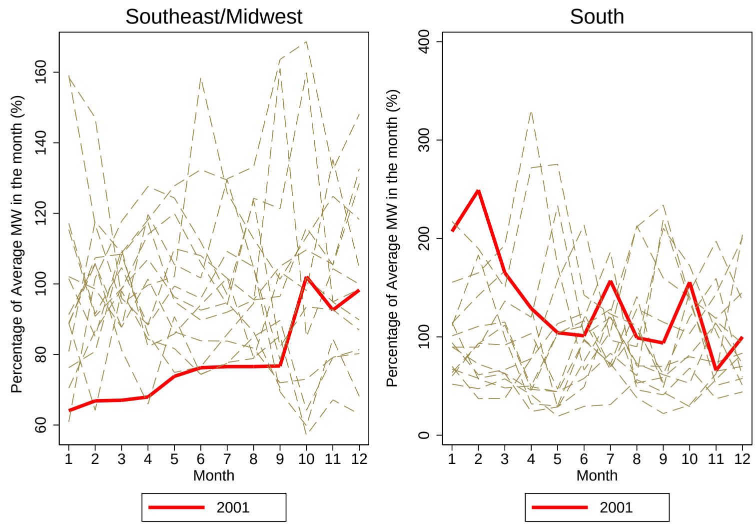

Figure A1: Streamflow Energy of Rivers as Percentage of Subsystems' Historical Average (1996-2010)

Notes. This figure presents the streamflow energy level of the rivers in each month as a percentage of the subsystem's historical average for each month. That is, a value 100 means that in that month-year the streamflow level was equal to the average streamflow level in that month of the year. Each line represents a different year from 1996-2010. As we can see, the streamflow level in the subsystem Southeast/Midwest in the first half of 2001 is practically the lower envelope of the historical series in the first months of the year. This low streamflow level triggered the rationing in early 2001. Source: National System Operator (ONS).

[35] Column 2 "Use less than before the rationing" stands for "use less", "is still switched off", "removed it" and "changed by a smaller one".

Table A1: Realized Electricity Demand as Percentage of Demand Forecast (%)

	Southeast	**Midwest**	**South**	**Brazil**
	(1)	(2)	(3)	(4)
1998	99.6	98.5	97.9	99.4
1999	95.6	96.4	97.5	95.6
2000	96.2	95.7	98.5	95.6

Notes. This table presents realized electricity demand in each subsystem and year as as a percentage of the demand forecast from the 1997-2007 Decennial Energy Plan (PDE) produced by the National System Operator with the Minning and Energy Ministry. PDE the plan that sets the ground for the expansion of the system in an horizon of ten years. That is, the 99.6 in the first cell means that the energy used in the Southeast in 1998 was 99.6 percent of the forecasted demand for that region and year in PDE (1997).

Table A2: Main Datasets Descriptive Statistics

	Electricity Data (ANEEL)	Habits of Energy Use (PPH)	Appliances Holdings (POF)
	(1)	(2)	(3)
Type	Administrative, panel	Survey, repeated cross section	Survey, repeated cross section
Time Period	Jan/97 - Dec/10, Monthly	1998/99, and 2004/05	1996/97, 2002/03, and 2008/09
Observation Unit	Utility Co.	Household	Household
Cluster Unit	Utility Co.	Utility Co.	State
Number of Clusters	44	10	11
Number of Observations	7686	14254	61342

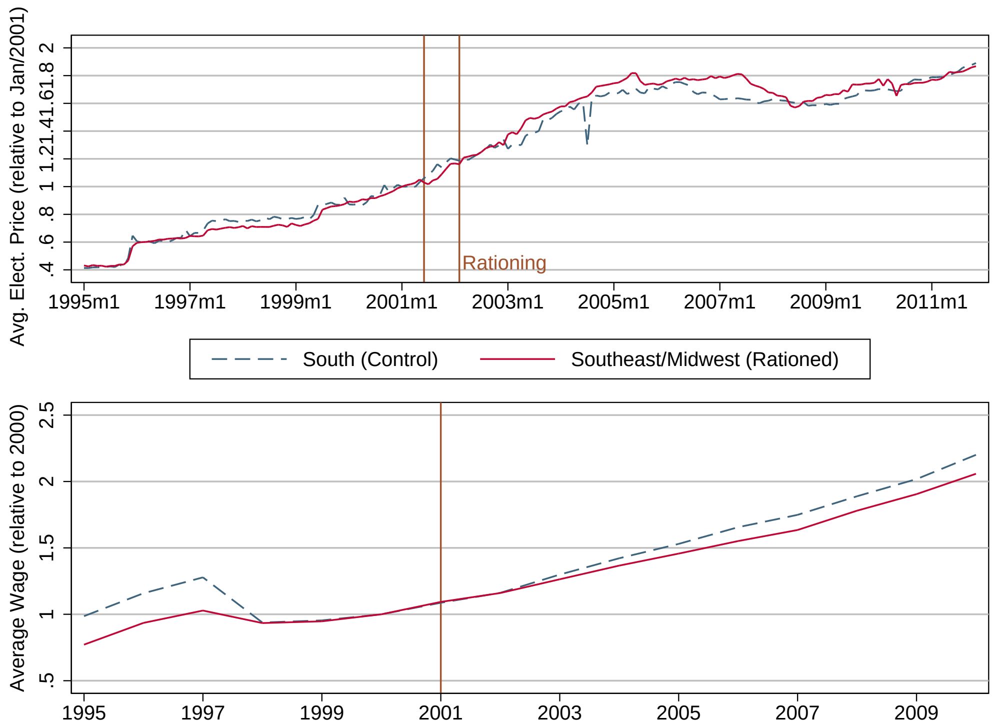

Figure A2: Evolution of Electricity Price and Wages Normalized to Pre-Rationing Levels

Notes. The first graph presents the monthly average electricity price in the South and Southeast/Midwest, normalized to prices of January 2001. The two vertical lines mark the rationing period. Data from the Regulatory Agency ANEEL. The second graph presents the annual average wage in the South and Southeast/Midwest, normalized to wages of 2000 (before the rationing). The vertical line mark 2001, the rationing year. Data from the Ministry of Labor's register (RAIS).

Table A3: Placebo Estimation (South and Southeast/Midwest)

	Households Connected to Electricity (1000s)	Real Electricity Price (R$)	Consumer Price Index	Average Wage (R$)	Employment (1000s)	Appliances Price Index	Share of Households Paying for Electricity	Average Household Size	Average Temperature (^0c)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
During*Rationing (β_D)	38.617	.008**	-.013*	76.515	14.877	-.028	-.004	-.044	-1.381***
	(35.584)	(.004)	(.006)	(45.513)	(20.751)	(.015)	(.042)	(.042)	(.252)
Post*Rationing (β_P)	83.116	.002	.035	155.184	13.249	-.026	.016	-.113	-.589*
	(97.097)	(.005)	(.027)	(112.812)	(46.795)	(.032)	(.023)	(.067)	(.301)
Data source	ANEEL	ANEEL	IBGE	RAIS	RAIS	FGV	POF	POF	INMET
Mean	770.3	.18	1.34	1037.1	2192.0	1.22	.88	3.31	22.9
Observations	7686	7686	1253	154	154	441	61311	61341	1813
Cluster level, i	44	44	7	11	11	8	11	11	11
Periods, t	179	179	179	14	14	60	2	2	168
R-squared	.976	.611	.995	.918	.943	.447	.023	.016	.874

Notes. This table displays the difference-in-differences estimates of the rationing effects on the rationed households during and post the intervention, captured by β_D and β_P from equation (2). Each column corresponds to the regression of a different dependent variable. *Sample* comprises the subsystems South and Southeast/Midwest. *Data sources:* administrative data from the Regulatory Agency (ANEEL) is at month-utility company level, between January 1997 until December 2010; Price Index from INPC (IBGE), at month-metropolitan area level; Ministry of Labor's register (RAIS) at year-state level; appliances price data used to calculate consumer price index IPC from IBRE (FGV), at month-metropolitan area level; household level microdata from the Household Budget Survey 1996/1997 (POF), estimations with sampling weights; and temperature from the National Meteorology Institute (INMET), at month-state level. All regressions with constant, period t and cluster level i fixed effects. Standard errors in parentheses are clustered by i according to data source as indicated. ***p<.01, ** p<.05, * p<.1.

Table A4: Placebo Estimation (North and Northeast)

	Households Connected to Electricity (1000s)	Real Electricity Price (R$)	Consumer Price Index	Average Wage (R$)	Employment (1000s)	Share of Households Paying for Electricity	Average Household Size
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
During*Rationing (β_D)	73.200*	.012*	.251***	-73.237***	81.678**	.183***	-.175***
	(35.271)	(.007)	(.008)	(23.078)	(30.919)	(.039)	(.056)
Post*Rationing (β_P)	282.049**	-.001	1.205***	-120.081***	195.761**	.187***	-.205***
	(111.217)	(.008)	(.027)	(39.774)	(77.300)	(.027)	(.048)
Dataset	ANEEL	ANEEL	IBGE	RAIS	RAIS	POF	POF
Mean	694.3	.16	1.35	767.20	1121.6	.79	3.84
Observations	3216	3216	537	210	210	59110	46341
Cluster level, i	18	18	3	15	15	16	16
Periods, t	179	179	179	14	14	2	2
R-squared	.956	.129	.998	.982	.945	0.045	.029

Notes. This table displays the difference-in-differences estimates of the rationing effects on the rationed households during and post the intervention captured by β_D and β_P from equation (2). Each column corresponds to the regression of a different dependent variable. *Sample* comprises the subsystems North and Northeast, excluding Pará where the rationing had a particular timming and target. *Data sources:* administrative data from the Regulatory Agency (ANEEL) is at month-utility company level, between January 1997 until December 2010; Price Index from INPC (IBGE), at month-metropolitan area level; Ministry of Labor's register (RAIS) at year-state level; household level microdata from the Household Budget Survey 1996/1997 (POF), estimations with sampling weights. All regressions with constant, period t and cluster level i fixed effects. Standard errors in parentheses are clustered by i according to data source as indicated.

Table A5: Hypothetic Average Appliances Electricity Consumption

	Appliance Specification	Daily Use	Average Monthly Consumption (kWh)
		(1)	(2)
Air Conditioner	Wall, $\leq$ 9000 BTU	8 hours	128.80
	Wall, 9001-14000 BTU	8 hours	181.60
	Wall, $>$ 14000 BTU	8 hours	374.00
	Split, $\leq$10000 BTU	8 hours	142.29
	Split, 10001-15000 BTU	8 hours	193.76
	Split, 15001-20000 BTU	8 hours	293.68
	Split, 20001-30000 BTU	8 hours	439.20
	Split, $>$ 30000 BTU	8 hours	679.20
Electric Shower	4500 Watts	32 minutes	72.00
	5500 Watts	32 minutes	88.00
Freezer		24 hours	47.55
Refrigerator	1 Door	24 hours	25.20
	1 Door, Frost Free	24 hours	39.60
	2 Doors	24 hours	48.24
	2 Doors, Frost Free	24 hours	56.88
Light Bulbs	Incandescent 40 Watts	5 hours	6.00
	Incandescent 60 Watts	5 hours	9.00
	Incandescent 100 Watts	5 hours	15.00
	Fluorescent 11 Watts	5 hours	1.65
	Fluorescent 15 Watts	5 hours	2.25
	Fluorescent 23 Watts	5 hours	3.45

Notes. This table presents the *hypothetical* average electricity use of appliances, calculated by the Brazilian energy efficiency program PROCEL based on technical characteristics of appliances and hypothetical utilization. I use these values to convert the effects in Section 5 into kWh. The complete table can be found in the website www.eletrobras.com/procel.

Table A6: Adoption of Energy-Saving Measures

	Energy Saving Measures									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Rationing Effect in 2005 (β_{05})	.004	-.014	.037**	.026	.206***	.414***	.280***	-.007	-.054	.011
	(.082)	(.015)	(.018)	(.023)	(.021)	(.024)	(.023)	(.041)	(.047)	(.053)
2005 Dummy(γ_{05})	.184***	.415***	.374***	.380***	.126***	-.002	.116***	.341***	.416***	.375***
	(.010)	(.010)	(.021)	(.023)	(.011)	(.011)	(.011)	(.022)	(.019)	(.024)
Mean	.789	.298	.294	.266	.177	.375	.263	.200	.315	.326
Observations	10747	10747	10747	10747	10747	10747	10747	10747	10747	10747
Utilities, i (cluster level)	10	10	10	10	10	10	10	10	10	10
R-squared	.054	.322	.446	.466	.359	.239	.344	.280	.170	.176

Notes. This table displays the difference-in-differences estimates of the rationing effects on the adoption of ten different energy-saving measures which are proxies for consumption habits, from equation (4) in Section 5. Each column corresponds to the regression of a different energy-saving measure as dependent variable, and present the marginal effects of logit estimation. Household level microdata is from the Appliances and Habits of Use Survey (PPH/PROCEL) 1998/1999 and 2004/2005. *Sample* comprises ten utility companies from the subsystems South and Southeast/Midwest. All regressions contain utility company, and year fixed effects, income, squared income, number of household members, build up area, and dummies for rich neighborhood and for proximity to "favelas". Standard errors in parentheses are clustered by utility company (10 clusters). Dataset does not contain sample weights. Energy-Saving Measures: *(1)* Switch off the lamps when leave the room for more than 30 minutes; *(2)* Do not open the fridge/freezer door fully; *(3)* Do not storing warm food in the fridge/freezer; *(4)* Do not dry clothes behind the fridge/freezer; *(5)* Verify the condition of fridge/freezer's rubber seals regularly; *(6)* Reduce shower time when using an electric shower; *(7)* Adjust the shower thermostat according to the ambient temperature; *(8)* Use washing machine in full load; *(9)* Accumulate clothes to iron; *(10)* Switch off the TV when not watching. ***p<.01, ** p<.05, * p<.1.

Table A7: Statistics from Qualitative Variables (Percentage of Respondents)

	South (1)	Southeast/Midwest (2)
Variation in life quality due to rationing?	(N=788)	(N=2668)
None	.48	.43
Uncomfortable	.02	.21
Very Uncomfortable	.00	.08
Learnt to have comfort saving money	.49	.28
Did you substitute incandescent light bulbs by fluorescent ones?	(N=1000)	(N=2819)
Yes, all.	.54	.32
Yes, more than half of them.	.00	.04
Yes, less than half of them.	.00	.07
No.	.45	.56
Do you still use fluorescent light bulbs?	(N=552)	(N=1160)
Yes, all of them.	.99	.69
No, I am back to incandescent ones.	.00	.22

Notes. This table displays the percentage of households in each region (column) who responded each of the questions (rows). Data from the Appliances and Habits of Use Survey (PPH) 2004/2005.

Table A8: What did you do with these appliances after the rationing? (Percentage of respondents in Southeast/Midwest)

		Use as before the rationing (1)	Use less than before the rationing (2)	Bought it after the rationing (3)
Refrigerator	(N=2716)	.88	.12	.00
Freezer	(N=542)	.60	.37	.02
Air conditioner	(N=219)	.28	.69	.03
Electric Shower	(N=2510)	.56	.43	.00
Lamps	(N=2730)	.46	.54	.00

Notes. This table displays the percentage of households in the Southeast/Midwest who responded the questions (columns) regarding each appliance (row). Data from the Appliances and Habits of Use Survey (PPH) 2004/2005.