Can Rationing Affect Long Run Behavior? Evidence from Brazil

Francisco J. M. Costa*

[PRELIMINARY AND INCOMPLETE]

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Abstract

Although there is significant empirical evidence that economic problems may have multiple solutions, the feasibility of using temporary interventions to induce individuals to switch to new stable steady states is still contentious. I examine whether an extreme policy - temporary electricity rationing - can affect long run household behavior. I look at evidence from a large 8-month compulsory rationing imposed on Brazilian households' electricity use in 2001. I exploit the exogenous implementation of the rationing in time and across regions in a quasi-experiment design. Evidence supports the existence of multiple steady states for households' electricity use. I find that the rationing program led to a persistent reduction on electricity use of 14% even a decade later. This long run effect is remarkably flat over time, and 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. This suggests that intense temporary interventions can be effective in inducing people to switch to steady states with smaller energy consumption.

JEL codes: D12, O13, Q41, Q48.

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[*] Department of Economics and STICERD, London School of Economics. E-mail: F.J.Costa@lse.ac.uk. I am grateful to Robin Burgess, Gilat Levy, Gharad Bryan, Gerard Padró i Miquel, and Greg Fischer for the encouragement. I appreciate the discussions with my colleagues at LSE, Cláudio Ferraz, Frederico Finan, Jerry Hausman, Matthew Kahn, Ralf Martin, Emilio Matsumura, Mushfiq Mobarack, Emerson Salvador, and seminar participants at LSE, PacDev 2012, EEA 2012, EconCon 2012, PSE, University of Cambridge (EPRG), IFS (EDePo), Thema, LBS, and the Granthan Institute for Climate Change. I also thank ANEEL, PROCEL/Eletrobrás, and IBRE/FGV for providing data. A very preliminary version of this paper started circulating in December 2011 with the title "Just Do It: Temporary Restrictions and New Consumption Habits".

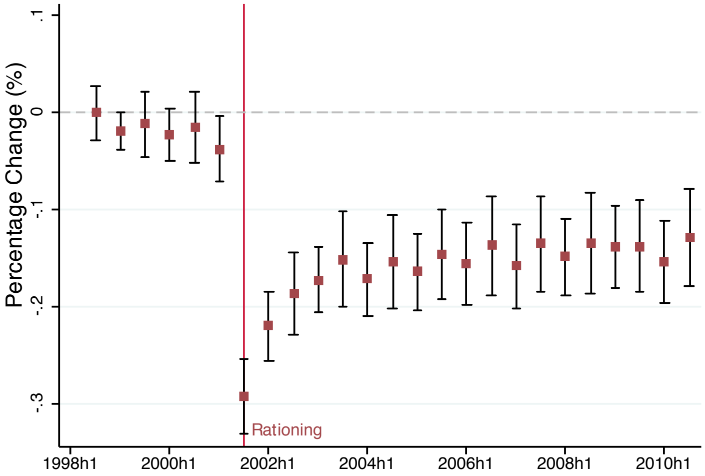
1 Introduction

There is significant empirical evidence of the persistent importance of historical episodes for current outcomes even when controlling for contemporary factors (Bloom et al. 2003; Dell 2010; Acemoglu et al. 2012; Bleakley and Lin 2012). This suggests that specific events can place similar economic agents in different steady states. Therefore, in some situations we may want to use policy levers to change steady states and generate long run effects, such as promoting energy conservation. However, the feasibility of using temporary interventions to generate such sustainable effects is still contentious. While Kremer and Miguel (2007) are not optimistic about this possibility, Dupas (2012) finds that individuals do change long run consumption pattern when interventions permit them to experience the full costs and benefits of their choices.

As economists, we think under an optimization framework. A whole class of economic models has multiple steady states. A common feature of these models is that marginal incentives have local effects only. However, stark interventions can have long run effects by making individuals switch steady states. Thus, to empirically assess if it is feasible to change steady states, one needs a big shock. Evidence from a related literature shows that marginal incentives, such as nudges, do make people switch equilibria in the short run, but rarely in the long run (Charness and Gneezy 2009; Acland and Levy 2011; Allcott and Mullainathan 2010).

I examine whether an extreme policy - temporary 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% during 8 months. I use the exogeneity afforded by the program's implementation across locations to interpret this episode as a quasi-natural experiment. This episode is an exceptional testing ground for a class of theories important for policy: it was a big and temporary intervention in an environment where a credible counterfactual was generated. I find evidence supporting the existence of multiple steady states in electricity consumption, and, further, that the average household can reduce electricity use by 14% in the long run by switching to a less energy-intensive steady state.

I first present a simple theoretical framework where individual consumption optimization have multiple steady states. In theory, multiplicity could emerge from many mechanisms, such as beliefs, social norms, reference-dependency, or learning (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 2011b, 2011a). The model presented illustrates using a simple mechanism: intertemporal complementarity of consumption (Becker and Murphy 1988).



Controls: Utility FE, semester FE, month FE, trend, real elect. price and real wage.

Figure 1: Rationing Effect on Average Household Electricity Use Over Time

I describe the 2001 Brazilian electricity rationing in more detail in Section 3. In short, in the beginning of 2001 the electricity generation capacity of some states was severely undermined due to unusual weather conditions. In order to prevent general blackouts, the government planned and implemented an emergency rationing program within a couple of months (Kelman 2001). In June 2001, households from the Southeast, Midwest and Northeast 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 in case of not meeting their target, and received bonuses for further energy saved. The restrictions on consumption were fairly unexpected by the households.[1] After the end of the program in February 2002, electricity supply and prices went back to normal.

I use explanatory variables closely related to the shock to assess the multiplicity of steady states. To estimate the rationing's impact on final household electricity consumption, I use a panel with monthly household electricity use and average price per utility company from 1998 to 2010, based on the utilities' records. To assess how the actual pattern of household electricity use was affected, I exploit unique household level microdata from a survey on appliance holdings and consumption habits from over 10 thousand families. I also use a second household level dataset with information on households appliances' inventory and vintage of more than 40 thousand families.

The main empirical strategy of this paper is a difference in difference specification, using households

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[1] Until May, the government was trying to reduce consumption with other measures and was planning to use only price schemes. See quotes from newspapers in Appendix B.2.

in similar non-rationed states as a control for the rationed households. In the body of the paper, I restrict attention the the most developed regions of Brazil, which are the Southeast, Midwest and South. Figure 1 plots the estimated coefficients that capture the rationing effect on average household electricity use in the Southeast/Midwest per six-month period from the second half of 1998 until the end of 2010. [2] While I do not observe strong anticipatory effects, I find that during the electricity crisis, marked with a vertical line, rationed households reduced monthly consumption around 46 kWh (28%) relative to non-rationed ones. I find that, from 2002 until 2010, the rationing caused a flat reduction of 25 kWh (14%) in average monthly electricity use. Most striking is the flatness across time of this estimates. These results are surprisingly robust to different specifications, controls and sub-samples. The total energy saved in the nine years after the rationing adds up to 59.4 TWh, which is equivalent to 13 months of initial household electricity use.

This remarkably persistent change gives some evidence that households settled in a new steady state with lower consumption levels. Microdata on consumption choices support the hypothesis that households actually changed their utilization of electricity services. Even three years after the rationing, I still find that rationed households maintained the lower level of freezer utilization, hours of use of lights, and electric shower temperature relative to the non-rationed ones. A back-of-envelope calculation suggests that only these variables correspond to around one third of the long run electricity use reduction. Further, I find an increase in the adoption of ten other energy-saving measures. These results are robust to different specifications. As shown in Appendix D, these effects are reasonably homogeneous in all income quantiles.

The reduction in electricity demand could also be caused by investments in energy-efficient appliances. However, microdata on appliance holdings suggests that durable goods did not play a major role in the long run effects. During the rationing, households seems 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 ares became older relative to the non-rationed ones. I present an extended version of the theoretical framework with endogenous choice of appliances characteristic in Appendix A. The empirical findings as a whole are consistent with it.

Taken together, this is strong 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.[3] Naturally, there are intrinsic potential issues for inference

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[2] Formally, it plots the coefficients of the interaction of dummies for year-semester and rationed region, as in equation (3) presented in Section 4, controlling for real wages and real electricity prices, and using households in the South as a control for those in the Southeast/Midwest.

[3] Time series evidence suggest that the rationing was a structural break in electricity demand (Maciel et al.

of long run impacts in this setting, 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.

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 results of the same magnitude. During the 2000 California energy crisis, public appeals reduced household electricity use by 7% (Reiss and White, 2008). Allcott (2011a) shows that social norms are one source of multiplicity of steady states of household electricity use. He presents a series of randomized controlled trials in which households reduce electricity consumption by 2.7% when they learn about the average consumption in their neighborhood. It is very likely that social norms also contributed to the effects observed in the Brazilian case studied here.

This paper also highlights the crucial importance of considering human behavior when designing energy and environmental policies. There is a heated debate on the magnitude of a “energy efficiency gap” in society, defined in terms of investment inefficiencies - that is, 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 analyses 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 change their appliance utilization pattern (Davis et al., 2012). As demonstrated, 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.

Few studies have formally evaluated energy efficiency programs in developing economies. Although I focus on the most developed areas of Brazil, the country’s electricity market still shares distinct features with other developing countries. Electricity demand in these countries has been growing at fast rates due to greater access to electricity and durable goods of the poorer population (Gertler et al., 2012). I document that appliance utilization of the lower income quantiles were also affected by the rationing. The evidence provided here suggests that demand management programs may be useful for developing countries as well.

2009).

The paper also indirectly relates to the rationing literature from the post-War and oil shock periods (Tobin, 1952; Neary and Roberts, 1980, Collier, 1986). Although several theoretical studies examined the impacts of rationing on consumers' choices and welfare, there is a more limited body of rigorous empirical evidence on these questions.[4] Furthermore, this literature mainly focuses on the short run effects of the consumption restrictions, and rarely discusses its potential long run impacts. I show that the short run restrictions do have large impacts on individuals' choices, even in a longer horizon.

The main contribution of this paper is to show that one can use intense temporary interventions to promote sustained changes in consumption behavior and promote energy conservation. As I discuss in the conclusion, one needs to make strong assumptions about the sources of multiplicity of steady states in order to do rigorous welfare evaluation of this policy.

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. Appendix A presents an extended version of the model accounting for investment in energy-efficient appliances. Appendix B describes the rationing in further detail. Appendix C contains further empirical results, and Appendix D provides evidence on heterogeneous effects.

2 Theoretical Framework

This section outlines the theoretical framework to guide the empirical analysis. It illustrates how temporary restrictions can generate long run effects when multiple steady states exist. Suppose an infinity lived individual, with exponential time discount rate $\beta < 1$. Every period the individual chooses ordinary consumption, c_t, and services from electricity, e_t. Assume preferences are such that electricity services consumed in 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* $c, e, s \geq 0$.

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[4] Cite soft evidence from post-War, Japan etc

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 electricity utilization. For example, the more one uses freezers to store frozen goods, the higher the marginal utility of using freezer today; or the more one showers in hot water, less enjoyable becomes a cold shower. Assume individual is fully aware about her preferences, and maximizes utility taking in 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 price of ordinary consumption to 1, and let electricity price be p. For simplicity, suppose no credit market.[5] Therefore, the individual solve the following dynamic optimization problem:

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

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 $w(e_t, s_t) \equiv u\left(y - pe_t, e_t, s_t\right)$. The policy correspondence which describes the optimal consumption path is defined by $s^*(s) \equiv \{s' | V\left(s\right) = w\left(s' - \delta s, s\right) + \beta V(s')\}$. 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). □

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.

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

Therefore, during the rationing the individual maximizes utility by solving problem (1) with the extra 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 bellow $\bar{e}$, the horizontal red line, 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 in 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 bellow 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, some households enter a new optimal path that converges to a steady state with lower utilization of electricity services.*

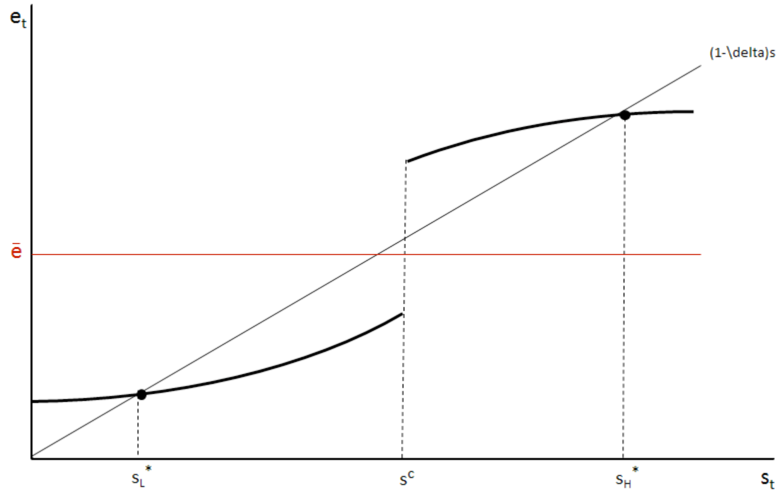

Figure 2: Illustration of Rationing Dynamics in an Optimization Problem with Multiple Steady States [Actual numerical solution soon]

In sum, if the optimization problem of recurrent consumption decisions has multiple steady states, a 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 class of models that generate multiplicity of steady states. The source of multiplicity of steady states is important when deriving welfare conclusions regarding the rationing and its dynamics. In particular, when the model generates Pareto-ranked steady states, for example when electricity use produces externalities or internalities. Since I cannot unveil the actual mechanism underlining the multiplicity of steady states, I cannot estimate the welfare costs of this policy.

Further, consider introducing a temporary marginal incentive, such as a marginal change in prices. 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 close to the original steady state level and individuals will converge back to their original steady states consumption levels. However, if the price change is sufficiently big - i.e., it is not a marginal change - then individuals may switch to new stable steady states.

I describe an extended version of this model in Appendix A, which explicitly accounts for strategic investment in appliances as in Dubin and McFadden (1984). Analogous to the main findings described, any persistent change in appliances acquisition are due to switching steady states. The extended model in closer related 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, provide summary statistics, and describe the data used.

The Brazilian electricity system heavily relies 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).[6]I restrict attention to the period after the privatization of the Brazilian electricity sector. Under the new regulatory mark, approved in December 1997, utility companies receive concessions to supply energy in delimited areas, and face no competition. The Regulatory Agency (ANEEL) defines the electricity price.[7]

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[6] The national grid is controlled by the National System Operator (ONS), which coordinates the electricity generation and transmission. The subsystems are connected with transmission lines which support a limited exchange between regions.

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

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$/kWh)	.157 (.009)	.162 (.005)	.153 (.004)	.148 (.004)
Share of households paying for electricity	.92 (.01)	.90 (.01)	.87 (.)	.79 (.01)
Panel B. Macro Covariates				
Consumer Price Index (base 2001)	.89 (.01)	.90 (.00)	.92 (.01)	.94 (.01)
Average wage (R$)	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 regions, in the columns, for the year 2000, except share of households paying for electricity from 1996/1997. 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 share of households paying for electricity from the Household Budget Survey 1996/1997 (POF) microdata by the Brazilian Geography & Statistics Institute (IBGE), calculated using sampling weights. *Panel B*'s statistics comes from three different sources: Consumer Price Index is from INPC index produced by IBGE, at month-metropolitan area level; and wages from RAIS, the data set with the Brazilian Ministry of Labor's registers, at year-state level; temperature from the National Meteorology Institute (INMET). The statistics in *Panel C* are from the 2000 National Census (IBGE) microdata.

Since the electricity system in the North and the Northeast was in an early development stage, I focus only on the regions of Brazil which electricity coverage was already high before the rationing, which are the South, Southeast and Midwest.[8] 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).[9]

As this report concludes, supply factors were the responsible for the 2001 collapse. Figure 3 shows the reservoirs level 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 ever. As a consequence, the reservoirs in the Southeast/Midwest reached critical levels, as can be seen in Figure 3.

In March 2001, ONS asked the federal government for an intervention in order to reduce demand by 20% in this region.[10] 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 on 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 only 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 was secure, and therefore these states were not rationed.

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[8] The electricity grid in the southern states was already developed in 2000, with more that 95% of electricity penetration among households. The was not true for the northern region, with electricity covering around 80% of households in some states. In the beginning of this century, the federal government lunched the program *Luz Para Todos* (Light For Everyone) which aimed to bring electricity to every household in the country. The northern states were the most affected by this policy, which increased electricity coverage to near 95% in less than a decade in these states. This substantially change the household sample composition, because a significant share of consumers in these states were not directly affected by the rationing.

[9] Table C.1 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. As we can see, the realized demand in this period was bellow the expected one, even when considering households market only. Further, the installed generation capacity would support the forecasted demand under regular natural conditions.

[10] Notice that in the begining of 2000, the reservoirs levels in the Southeast/Midwest were in a critical level similar to 2001, and the reservoirs in the South were bellow average as well. However, these regions experienced above average stream-flow iin 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 (Kelman 2001).

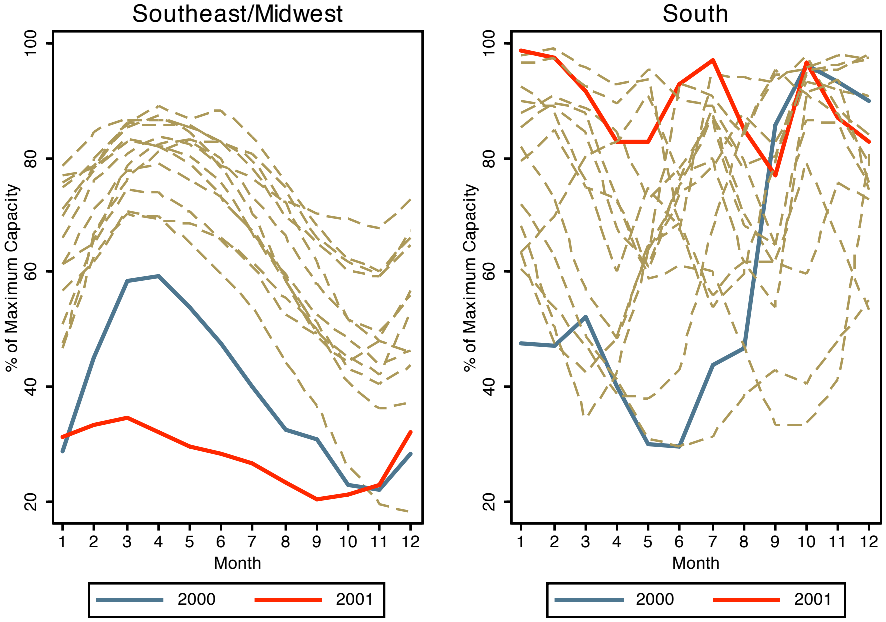

Figure 3: Reservoir Levels as Percentage of Subsystems' Maximum Capacity (1996-2010)

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 window.[11] Households with monthly average consumption above 100 kWh[12] 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 bellow 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 a 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.

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

[12] 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. Please, refer to the Data Appendix for details on the data cleaning and a complete list and description of all variables used.

3.1.1 Electricity Data

Electricity data is from the Brazilian Electricity Regulatory Agency (ANEEL) balance sheets, with the monthly transactions of each utility company. 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, monthly from January 1998 until December 2010. Average electricity use per household in each utility is calculated by dividing the total electricity sold to households by the number of consumers. The prices exerted by each utility company are defined by the Regulatory Agency (ANEEL), and there are two tariff bands for residential consumers: the regular and the social tariff. Since there is no retrospective disaggregate 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 Use

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 receive the visit of an interviewer, as is done in a census survey. The questionnaire includes both objective questions on the household characteristics and habits, as well as qualitative questions. Although most of the information is self-reported, the interviewers are supposed to check some of the information, for example, the number of lamps in the leaving room, and the characteristics of the main refrigerator.

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. Data contains information of more than 15 thousand households from more than 14 utility companies. To the best of my knowledge, this is the first time this survey is being used in social sciences. The main variables used in the paper are: the number of appliances permanently in use, hours of use, electric shower's thermostat regulation, and the adoption of ten energy-saving measures.[13]

In the 1998/1999's survey, households were asked which of these ten energy-saving measures were regularly adopted. However, the 2004/2005 survey asked three different questions: which of these measures used to be regularly adopted before the rationing; which were adopted during the rationing; and which were currently being adopted by the household. I will use these three questions to compare the appliances utilization habits of 1998 households with how the 2005 households claimed to behave before the rationing, what they claimed to have done during the rationing, and their current utilization habits. I aggregate these ten variables into one index of energy-saving measures following Katz, Kling and Liebman (2004).[14]

3.1.3 Appliances Holdings

Data used to assess appliance holdings are from the Household Budget Survey (POF), a national survey conducted by 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 micro data from the three last surveys, which are 1996/1997, 2002/2003 and 2008/2009. All surveys were conducted between July from the base year and June from 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. Also, although a household may declare having more than one house, I discard second houses and restrict attention to the main domicile.

Data contains characteristics from around 61 thousand households in eleven different states. Micro data contains the quantity of appliances owned by the households and the year these appliances were bought. It does not have details about the model of these appliances, neither if the appliance were bought new or second-hand. Since the estimate of the year an old appliance was bought

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[13] Namely: (1) Switch off the lamps when leave the room for more than 30 minutes; (2) Limit the opening/closing of the fridge/freezer door; (3) Avoid storing warm food in the fridge/freezer; (4) Avoid drying clothes behind the fridge/freezer; (5) Regularly verify the condition of fridge/freezer's rubber seals; (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 in active use.

[14] These indeces 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 inputted at the group mean.

is subject to severe measurement errors, I truncate appliances' age at 15 years. Also, 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 in 2002/2003 had less than two years old 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 variables used are the appliance's quantity, age and New dummy.

At last, 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 (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 access the characteristics 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 neither own a generator. Since these households who do not pay for electricity were not subject to the rationing's incentives, I include only electricity-payers in the main specification of the paper. As a robustness check, I use the non-payers as a second control group within each region and perform a triple difference specification.

3.1.4 Remaining Data

Nominal wages and number of workers are aggregated by year-state, and come from the RAIS dataset collected by the Brazilian Ministry of Labor. This dataset includes all workers in formal employment. Consumer price index is INPC produced by the Brazilian Geography & Statistics Institute (IBGE). These are 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. 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). These are micro data with daily measures for each of 45 meteorological stations in the region. Remaining information is from the National Census 2000.

4 Empirical Methods and Main Results

The main identification strategy to estimate the short and long run effects of the rationing is a difference in difference 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 series of assumptions. Before listing and assessing the plausibility of them, I present the basic regression form:

$$Y_{iat} = \alpha + \beta_D During_t * Ration_a + \beta_P Post_t * Ration_a + \gamma_D During_t + \gamma_P Post_t + \gamma_t t + \gamma_a + \gamma_m + \gamma X_{iat} + \epsilon_{iat} \tag{2}$$

where Y_{iat} is the dependent variable of observation i in area a at time t. $During_t$ and $Post_t$ are dummies equal to one for years during and after the rationing respectively, $Ration_a$ is a dummy equal to one if the area was rationed, t is time trend, γ_a and γ_m are area and month fixed effects, and X_{iat} is a vector of covariates - for example, real wage, and real electricity price. Area, a, stands for the cross section unit of the dependent variable, which in this section is the utility company. I do not impose any structure on the errors correlation over time and cluster errors at area level, a, as Bertrand et al. (2004). The parameters of interest are β_D and β_P, which capture the effects of the rationing program by itself.

The estimates of β_D can be interpreted as the program's causal short run effect on the treated[15] if the treatment allocation is exogenous to households' electricity use [*Assumption 1*], and the evolution of electricity consumption in the South and the Southeast/Midwest were following a common trend before June 2001 [*Assumption 2*]. The validity of β_P requires also that there is no divergence in the time series of electricity use and covariates over the years [*Assumption 3*].

Section 3 provides clear evidence supporting *Assumption 1.* The official diagnosis of the energy crisis concludes that supply factors aggravated by severe weather conditions 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. However, these are the most developed regions of Brazil, with the Southeast being the richest region with the

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[15] It is worthy to highlight that, since the rationing program implemented a series of measures, this treatment here is the rationing program faced by households as a whole net the effects of pure information provision and subsidies, which were implemented in teh South as well. For example, one could argue that the efficiency campaigns in the rationed areas were more intense than in the non-rationed ones. Unfortunately, I am unable to formally disentangle any difference in treatment intensity. Evidence from the Californian public appeal and informaiton campaigns found short run effects which are about half of the ones found in the Brazilian case, and consumption bounced back to initial levels shortly after the end of the program.

two largest cities. Thus, despite some differences, average household electricity use is statistically equivalent in the two regions prior 2001 when we control for income and prices. Tables C.1 and C.2 present results from testing mean equality and common trend hypotheses. I reject that electricity consumption in the two regions were following a common trend prior 2001. As shown in Figure 1, average electricity use in the Southeast was growing around 1.3% a year less than in the South. I address this issue by allowing different trends in one specification, as in Angrist and Pischke (2009).

Assumption 3 is the key challenge of assessing long run impacts of any policy: to maintain a meaningful counterfactual for several years. In order to overcome this issue, I follow the historical literature and use different regressions specifications controlling for a series of contemporary covariates. Table C3 presents the mean difference of several covariates before and after the rationing, and a simple difference in difference to illustrate their evolution in the period. I find no difference on the evolution of all variables, except that temperature seem to have increased $0.5^o c$ in the South in the last decade. This would bias the estimates downwards.[16] Further, I do not find strong evidence of migration across the regions[17], or that households evaded rationing by spreading usage across more meters or irregular connections.[18]

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

4.1 Main Results

Figure 1 in the introduction presents the coefficients of the rationing effect on each six month period, from the second half of 1998 until the end of 2010.[19] Formally, it plots the coefficients of

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[16] Temperature in the Southeast virtually did not change relative 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-difference results would underestimate the actual effect of the rationing.

[17] 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.

[18] 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.

[19] I combined the 8 months from the rationing as the second half of 2001. That is, in the regression 2nd half of 2001 spans from June 2001 to February 2002.

the interaction semester and rationed region dummies, β_s, in the equation below

$$Y_{ist} = \alpha + \sum_{s} (\beta_s Semester_s * Ration_i) + \gamma_i + \gamma_s + \gamma_m + \gamma_t t + \gamma X_{ist} + \epsilon_{ist} \tag{3}$$

where Y_{ist} is the log of average electricity use in utility i, in year-semester s, and year-month t. Further, γ_i, γ_s and γ_m are utility, semester-year and month fixed effects, γ_t is a linear time trend, and X_{ist} is a vector of controls containing real electricity price and real wage. Since the rationing was implemented only in June 2001, these coefficients capture potential anticipatory effects. As previously argued, consumption in the Southeast was decreasing relative the South, but we cannot observe strong anticipatory effects during the first months of 2001.

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 28% relative to the ones in the South region in the same period. 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 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 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 (Angrist and Pischke 2009), 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.[20] 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 a 12% reduction in long run electricity use. Column 8's specification controls for a triple interaction of period-utility-price and

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[20] 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.

period-utility-wage, where period are dummies for the period prior June 2001 and after it. This specification allows that these utility-specific elasticities change during the rationing to account for structural breaks, as found by Maciel et al. (2009). The rationing effects gets even bigger in this case.

Last, columns 9 and 10 address potential issues with the sample of the data. Column 9 presents the rationing effects excluding the two biggest metropolitan areas from the sample - São Paulo and Rio de Janeiro. Column 10 presents results excluding states from the Midwest, which tend to be less urbanized than the Southeast. In both cases, I observe virtually no difference in the estimates.

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 after one year and is flat since 2003, supporting the multiple steady states story.

5 Channels of Persistence

In this section I use household level microdata to shed light on the channels supporting the long run reduction in electricity demand. I first present direct evidence that the utilization choices of individuals were affected by the rationing. Then, I examine whether the stock of appliances in the Southeast/Midwest became relatively more energy-efficient than the Southerner one in subsection 5.2.

I use the same identification strategy described in the previous section, but I need to attend to one caveat. By 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 section presents results from the Appliances and Habits of Use Survey (PPH) 1998/1999 and 2004/2005. Table 3 presents the estimates of a difference in difference regression (2) controlling for region 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").[21]

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[21] Note that these two latter dummies are not collinear.

Table 2: Estimation Results

	Dependent Variable: Log of Average Electricity Use									
	Regions South, Southeast, and Midwest								Drop SP/RJ	Drop Midwest
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
During*Rationing (β_D)	-.283**	-.278**	-.281**	-.274**	-.290**	-.281**	-.268**	-.454**	-.276**	-.291**
	(.010)	(.010)	(.011)	(.011)	(.012)	(.011)	(.011)	(.109)	(.010)	(.011)
Post*Rationing (β_P)	-.140**	-.139**	-.139**	-.136**	-.170**	-.137**	-.121**	-.314**	-.138**	-.136**
	(.012)	(.013)	(.013)	(.013)	(.012)	(.013)	(.013)	(.109)	(.013)	(.014)
Utility Fixed Effects	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Real Electricity Price	.	✓	✓	✓	✓	✓	✓	✓	✓	✓
Real Wage	.	.	✓	✓	✓	✓	✓	✓	✓	✓
Temperature	.	.	.	✓	.	.	.	.	.	.
Different Trends	.	.	.	.	✓	.	.	.	.	.
Cubic polynomial	.	.	.	.	.	✓	.	.	.	.
Covariates-Utility Interacted	.	.	.	.	.	.	✓	.	.	.
Covariates-Utility-Period Interacted	.	.	.	.	.	.	.	✓	.	
R-squared	.88	.88	.88	.89	.88	.88	.90	.91	.88	.86
Observations	6807	6807	6807	6671	6807	6807	6807	6807	6495	6027

Notes. This table displays the OLS estimates of equation (1) in the text. The dependent variable is log of average household electricity use taken from the Electricity Regulatory Agency (ANEEL) balance sheet, which is at month-utility company level. Each column corresponds to a different regression, using the specifications indicated in the rows. Nominal electricity price and wage are from ANEEL and the Brazilian Ministry of Labor's register (RAIS) data sets, respectively. I compute prices and wages in real terms by dividing nominal variables by the Consumer Price Index (INPC/IBGE). Temperature is from the National Meteorology Institute (INMET). A Levin–Lin–Chu Test rejects the hypotheses that these variables are non-stationary series. The *sample* spans from January 1998 until December 2010. Columns 1 to 8 includes all the 44 utility companies from the subsystems South, Southeast/Midwest. Column 9 includes all utilities except the two serving the main metropolitan areas Sao Paulo (Eletropaulo) and Rio de Janeiro (Light). The sample used in Column 10 excludes the five utilities from the Midwest. Standard errors are clustered by utility company. Regressions with constant, time trend, month fixed effects, During and Post-Period fixed effects. *Controls*. "Different Trends" includes a specific time trend for the rationed areas (Angrist and Pischke 2009, page 238). "Cubic polynomial" adds quadratic and cubic terms of real prices and real wages as controls. "Covariates-Utility Interacted" stands for the interaction RealPrice*Utility and RealWage*Utilities, which aim to capture a utility-specific price and wage sensitivity. "Covariates-Utility-Period Interacted" stands for the interaction RealPrice*Utility*BeforeRationing, RealPrice*Utility*AfterRationing, RealWage*Utilities*BeforeRationing, and RealWage*Utilities*AfterRationing, which aims to capture any potential change on each utility-specific price and wage sensitivities implied by the rationing. **p<.01, * p<.05, + p<.1.

Table 3: Results on Consumption Habits

	Appliances Always Switched On		Hours of Use Per Week				Thermostat	Adoption of Energy-Saving Measures		
	Fridge	Freezer	AC	All Lamps	Incandescent Lamps	Fluorescent Lamps	Electric Shower	Before Rationing	During Rationing	Currently
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
2005*Ration	.3**	-1.6**	.2	-1.6*	-2.3*	-1.7**	-3.2**	.03+	.13*	.10*
	(.04)	(.01)	(.03)	(.07)	(.08)	(.02)	(.35)	(.003)	(.003)	(.003)
Sample Mean	1.0	.9	4.4	13.8	10.7	10.3	1.3	-.06	-.04	-.04
R-squared	.06	.06	.04	.20	.09	.08	.11	.05	.04	.05
Observations	11629	2263	793	12716	12057	4242	11541	12644	12644	12644

Notes. This table displays the difference in difference estimates of the rationing effects on different proxies for consumption habits. Micro data used is from the Appliances and Habits of Use Survey (PPH) 1998/1999 and 2004/2005 conducted by the energy efficiency program (Procel) of the national electricity company (Eletrobras). Each column corresponds to a different dependent variable and appliance. Columns 1,2, and 7 uses a ordered logit estimation, and Columns 3-6 and 8-10 uses a OLS estimation. All regressions contain region fixed effects, year fixed effects, income, squared income, number of household members, build up area, and dummies for rich neighbourhood and for proximity to "favelas". Standard errors are clustered by treated region. The data set does not have sampling weight. In Columns 1-2, "Appliances Always Switched On" stand for the number of appliances that are in permanent use conditional on ownership. Columns 3-6 refer to the total number of hours of AC and lamps used per week conditional on ownership. Electric shower thermostat in column 7 can have three levels: 0 (Off), 1 (Summer), or 2 (Winter). "Energy-Saving Measures" corresponds to the adoption of 10 different actions which are aggregated as Katz, Kling and Liebman (2004). The 2004/2005 survey asked which measures the household used to take before the rationing, which were taken during the rationing and which were still beeing adopted. The estimates presented in columns 8-10 correspond to the difference in difference estimation comparing adoption in 1998/1999 with what households in 2004/2005 claimed to adopt before, during and after the rationing. Please refer to Section 3.1 for details about these variables. **p<.01, * p<.05, + p<.1.

Table 4: Results on Appliances Holdings

	Refrigerator			Freezer			AC		
	Quantity	Vintage	New	Quantity	Vintage	New	Quantity	Vintage	New
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A. Difference in Differences									
Rationing Effect in 2002	.10	-.37**	.32*	-.40*	.02	-.78*	.49+	.67**	-1.25**
	(.26)	(.06)	(.16)	(.20)	(.13)	(.39)	(.29)	(.20)	(.28)
Rationing Effect in 2008	.08	.02	.10	-.52*	.01	-.35*	-.02	.71**	-1.10**
	(.24)	(.04)	(.12)	(.23)	(.15)	(.15)	(.27)	(.08)	(.18)
Sample Mean	1.0	6.8	.09	.20	7.4	.07	.13	6.2	.11
R-squared	.06	.01	.01	.12	.01	.04	.20	.01	.03
Observations	52805	48733	48733	52805	11279	11279	52805	4356	4356
Panel B. Triple Difference									
Rationing Effect in 2002	.56	-.43+	.01	-.13	-.26	-.76	-.49	-.39	11.23+
	(.54)	(.24)	(.24)	(.46)	(.67)	(.54)	(.37)	(.45)	(6.38)
Rationing Effect in 2008	1.11+	-.38**	.09	-.14	-.74	.06	-.22	-1.06*	12.20
	(.64)	(.12)	(.21)	(.27)	(.51)	(.94)	(.40)	(.52)	(9.78)
Sample Mean	.98	6.7	.10	.20	7.3	.07	.13	6.1	.11
R-squared	.09	.01	.01	.13	.01	.04	.21	.01	01
Observations	61311	54832	54832	61311	12578	12578	61311	4738	4738

Notes. This table displays the estimates of the rationing effects on the average stock of appliances, using microdata from the Household Budget Survey 1996/1997, 2002/2003 and 2008/2009 (POF/IBGE). *Panel A* presents the results of a difference in difference estimation comparing households who pay for electricity in the South with those in the Southeast/Midwest. *Panel B* contains the rationing effects estimated using a triple difference specification that compares the different evolution of the stock of appliances of households who pay for electricity in the South and Southeast/Midwest, with the evolution of appliances owned by households irregularly connected to electricity in these two regions. Please refer to the text for more details on this specification. Each column corresponds to a different dependent variable and appliance. *Quantity* means the number of appliances in the domicile. *Vintage* is the number of years since the appliance was bought, bunching all ages above 15 years old together. Regressions of these two dependent variables are estimated using ordered logit. *New* is a dummy variable equal to 1 if appliance was bought less than two years ago, and zero otherwise. 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 impact on the share of appliances bought during the rationing. Regressions of Vintage and New variables are *conditional* on appliance ownership. All regressions with state fixed effects, year fixed effects, income, number of household members, and a dummy for rural regions. Regressions in Panel B also contains a dummy for electricity payers, and region-payers, region-year, and year-payers fixed effects. Standard errors are clustered by state (11 clusters). All regressions use sampling weights. **p<.01, * p<.05, + p<.1.

We can see in column 7 that the thermostat of electric showers became 68% more likely to be regulated in "summer mode" than in "winter mode".[22] Column 2 shows that households who own a freezer in the Southeast/Midwest become less likely to have it permanently switched on relative to households in the South. We see in column 1 that this was partly compensated by bigger utilization of refrigerators, but in a smaller scale. While a freezer became 19% less likely to be always in use, refrigerators became only 3.5% more likely to be permanently in use. We can also observe in column 4 that the rationing reduced by 90 minutes the number of hours of light use per week, which represents roughly a 6% reduction. Looking at columns 5 and 6, one cannot reject that utilization of both incandescent and fluorescent light bulbs were equality affected. We do not observe a statistically significant difference in the utilization of air conditioners, but the small sample size may undermine the results.

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. A back-of-envelope calculation suggests that these three dimensions of electricity use - refrigerator/freezer, lamps and electric showers - account for one third of the long run effect.[23]

Columns 8 to 10 of Table 3 present the rationing's effects on the adoption of 10 energy efficient measures. As described in Section 3.1.2, I use retrospective reports to compare adoption in 1998/1999 with what households in 2004/2005 claimed to adopt before the rationing, what they claimed to have adopted during the rationing, and which measures were currently adopted. I find that households in the Southeast/Midwest became relatively more likely to adopt energy-efficient measures during the rationing than the Southerns ones. Furthermore, I observe that the rationing had a positive effect in the current adoption of these measures. These results still hold, albeit not all significantly, for each of the 10 energy-efficient measures individually. This is evidence that the new consumption pattern emerged during the rationing, with stable effects at least 3 year later. Results are qualitatively unaffected using different specifications.

5.2 Electrical Appliances Holdings

This section assesses if the rationing affected the average stock of appliances, using data from the Habits of Use Survey and the Household Budget Survey (POF) 1996/1997, 2002/2003 and

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[22] The average electric shower in "summer mode" consumes 30% less electricity than in the "winter mode".

[23] Back-of-envelope are based on the following calculation for each variable: [Average number of appliance per household] * [Average electricity consumption per appliance] * [Estimated effects on appliance utilization].

Table 5: Results on Appliances Holdings (Continued)

	Dependent Variable: Appliance Quantity			
	Lamps All (1)	Lamps Incandescent (2)	Lamps Fluorescent (3)	Electric Shower (4)
2005*Ration	-.22*	.75**	-.90**	-.11*
	(.01)	(.01)	(.01)	(.06)
Sample Mean	8.4	6.8	1.6	.93
R-squared	.46	.32	.22	.10
Observations	12728	12728	12728	12728

Notes. This table displays the difference in difference estimates of the rationing effects on the average stock of appliances, using micro data from the Appliances and Habits of Use Survey (PPH) 1998/1999 and 2004/2005 conducted by the energy efficiency program (Procel) of the national electricity company (Eletrobras). Each column corresponds to a different dependent variable and appliance. Regressions of Lamps, the first three columns, use OLS and Shower reggression use ordered logit estimation. All regressions contain region fixed effects, year fixed effects, income, squared income, number of household members, build up area, and dummies for rich neighbourhood and for proximity to "favelas". Standard errors are clustered by treated region. The data set does not have sampling weights. **p<.01, * p<.05, + p<.1.

2008/2009, and Appliances and Habit of Use Survey (PPH). I restrict attention to the five appliances that represent 85% of average household electricity use (Procel, 2007): refrigerators, freezers, air conditioners, lamps, and electric showers. I use three variables to assess appliances inventory, the quantity of appliances owned, the age of each appliance, and the dummy New which is equal to one if appliance was bought within the last two years.

Panel A in Table 4 presents the estimates of the difference in difference regression (2) using POF data controlling for state fixed effects, year fixed effects, income, 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. I find that the rationing had no effect on the average quantity of refrigerators and air conditioners, however it reduced the average number of freezers in the Southeast/Midwest relative to the South (columns 1, 4 and 7).

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 this appliance, but it did make the average refrigerators become more likely to be *New*. However, this effect dissipates over time and I find no effect on the stock of this appliance in 2008/2009. Columns 4, 5, 8 and 9 suggest that households postponed the substitution of freezers and air conditioners during the rationing. More interestingly, by 2008/2009, the stock of freezers in the Southeast shrunk by 7%, and both freezers and air conditioners became relatively older in the Southeast/Midwest. These results are robust under different specifications and restricting to subsamples.

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. I describe the extended theoretical framework in Appendix A. By the 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.[24] 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.

As a further robustness check for the short run effects, I run a triple-difference using households who do not pay for electricity as a control group within the rationed areas (refer to Section 3.1.3). These are households irregularly connected to the grid and, consequently, not rationed. The signs of the coefficients of refrigerators and freezers do not change, although some statistical inferences are affected. I do not trust the estimates of this specification to assess air conditioners due to the small number of this appliance owned by non-paying households. This specification should be considered only as a robustness check, because identification here requires even stronger assumptions. For this reason I do not trust the long run estimates produced by this specification, even as a robustness check.[25]

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 Table 5, I find that rationing led to a 2.5% reduction in the quantity of lamps and a reduction in the number of electric showers of around 9%.

In sum, 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

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[24] In the Brazilian case, the rationing started during winter, when air conditioners are less indispensable.

[25] For example, the assumption that income and life conditions of payers and non-payers followed the pre-rationing trend during the last decade is not very plausible. In particular because, after 2003, the government rolled-out a series of policies targeting low income households, including a large cash transfer program.

must be supporting the persistent reduction on electricity use.

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 change equilibria 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 intense temporary interventions to promote sustained changes in consumption behavior and promote energy conservation. I observe that household electricity use can have multiple steady states, and that people can switch to steady states with smaller energy consumption in response to temporary restrictions on electricity use. The long run effect is surprisingly stable over time. The energy saved has been equivalent to more than one months-worth of electricity every year, for the last 10 years and counting.

Although it is not clear if it is desirable to implement restrictions all around, this episode suggests that such intense interventions may be a cost one has to pay in order to generate long run effects from one-shot interventions. Following this line, 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. A second advantage relative to this literature is that the explanatory data used to examine the multiple steady states is closely linked with the intervention. That is, I use final electricity use and microdata on utilization of electric appliances to evaluate the long run effects of restrictions on electricity use.

A caveat of this paper is that I cannot disentangle which mechanisms generate the multiplicity of steady states sustaining the long run effects. Understanding the precise model driving the results is crucial to estimate the cost of the transition. A rigorous welfare analysis of the rationing hinges on the precise estimation of the short run costs of the rationing. Since it is very delicate to point out one single model, and I do not have enough empirical evidence to do so, I leave this for future work. Appendix C.3 presents evidence from qualitative data on this point.

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A Theoretical Framework Extended

Suppose a two-stage decision process. On 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 appliances be ordered in increasing energy efficiency of portfolio, i.e., $i = I$ is the most energy-efficient portfolio. The rental price of appliance i is r_i in annualized terms. The first stage optimization problem can be represented by

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

where $V\left(\Theta_i, s_t\right)$ 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.

On 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

$$\begin{aligned} W(s_t) &= \max_{i \in 1,2,\ldots,I} \left\{ V\left(\Theta_1, s_t\right), \ldots, V\left(\Theta_I, s_t\right) \right\} && (4) \\ V\left(\Theta_i, s_t\right) &= \max_{c_t, e_t} u\left(c_t, e_t, s_t\right) + \beta W(s_{t+1}) && (5) \\ &s.t.\ c_t + p e_t \leq y - r_i \\ &\qquad s_{t+1} = \delta s_t + e_t \\ &\qquad e_t = f(E_t|\Theta_i). \end{aligned}$$

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 $c_t + \pi\left(p|\Theta_i\right) e_t \leq y - r_i$, where $\pi\left(p|\Theta_i\right)$ is the marginal cost of producing one extra unit of electricity service, e_t. Following Davis (1997), I call problems (2) the *durable*, and (3) the *utilization problems.*

Proposition 1 in Section 2 characterizes the solution of the utilization problem. We argued that that for each appliance portfolio Θ_i, utilization converges to a stable steady state. The dynamics in the two stage problem will follow a similar pattern, since more energy-efficient appliances are associated with steady states with higher consumption of electricity services. Note that the marginal cost of electricity services, $\pi\left(p|\Theta_i\right)$, is smaller the more energy-efficient the appliances portfolio i. This makes an individual who choose more efficient appliances consume more services from electricity, assuming the income effect of electricity prices to be sufficiently small. Therefore, for any initial stock of electricity use s_t, the optimal appliance choice and utilization of electricity services will 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 choice during the rationing, if one would invest in efficiency or not, 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 "thermal comfort" and air conditioners, would be less utilized and, consequently, would receive less investments.

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

Once the rationing is over, incentives regarding durables are back to normal, and the individual is back to the unconstrained problem (2) and (3). 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 possible directions. An individual who invest more in energy efficiency during the rationing will be able to sustain a higher utilization level and would be less likely to reduce enough stock of consumption to converge to a lower steady state. Those who reduce utilization during the rationing and postpone investments, will use even less services from electricity and will be more likely switch steady state. Those who join a new optimal path, will converge to a steady state with lower services utilization, and weakly less energy-efficient portfolios.

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.*

At last, other sources of persistence could emerge when we aggregate these individuals in the market. If a sufficient mass of people switch steady state, the long run reduction of electricity utilization would shift down the electricity and appliances demand curves. This could lead to general equilibrium effects on prices, which are not explicitly modeled here. The effect of a reduction in electricity prices on utilization is ambiguous, because at the same time that it increases the steady state utilization level of each durable portfolio, it affects the incentives to invest in appliances' energy-efficiency.

B Rationing Timeline and Further Details

Table B.1: Realized Electricity Demand as Percentage of Demand Forecast (%)

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

Notes. Data from 1997-2007 Decennial Energy Plan (PDE) and the National System Operator (ONS).

Figure 3 shows the reservoirs level as a percentage of their maximum capacity for the subsystems SE and S, from 1997 to 2001. As we can see, during the first half of 2000, the reservoir levels from both subsystems were bellow the historical average of that period of the year, due to low stream-flow during the end of 1999.[26]However, as can be seen in Figure C.1, above average stream-flow during the begining of 2000 guaranteed electricity supply for that year. Despite the sizable risks of electricity shortage, no concrete measure was taken by the government in 2000.

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[26] By January 2000 the probability of a default of the subsystem SE was sizable. On a technical report published in 1999 (Nota Técnica ONS-DPP 059/1999), ONS presented simulations with 66 possible hydrological scenarios for 2000 based on the actual reserve levels at 30 November of 1999. The report shows that the reservoir levels in some regions would hit zero (i.e., zero energy reserve) in 9 of these scenarios. This represent a risk of default of the electric system equal to 13%, way above the 5% safety level required by the Regulatory Agency.

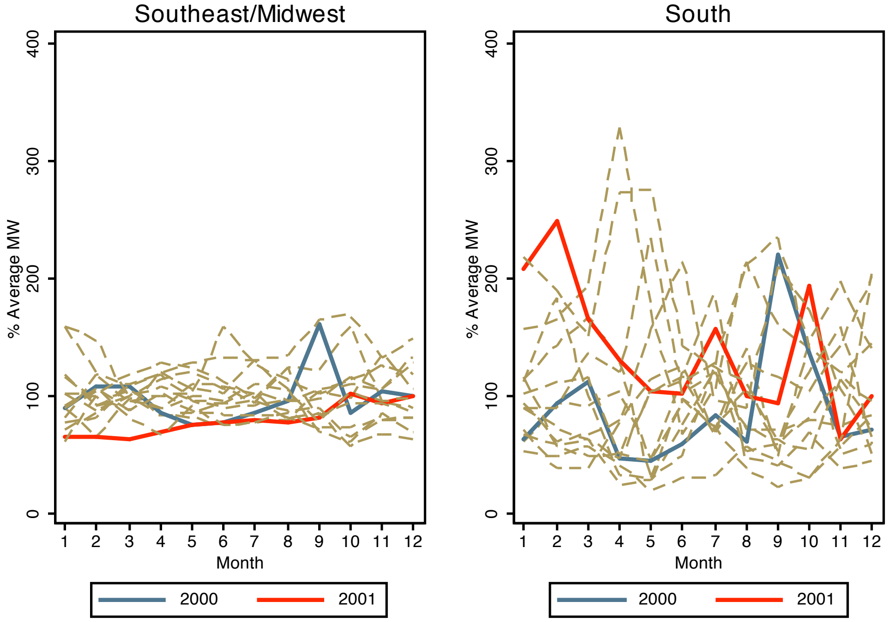

Figure B.1: Streamflow Energy of Rivers as Percentage of Subsystems' Historical Average (1996-2010)

In 2001, however, Brazil was not that lucky. As pointed by Kelman (2001), the nature was crucial for the timing and triggering of the electricity crisis. However, the severe weather conditions by themselves would not be enough to explain the severity of 2001's shortage. The non realization of the planned supply expansion was crucial to the reserves levels had reached the bottom. We can point to mainly two problems: (i) delays in the start of operation of generation and transmission units which had been planned to be inaugurated between 1998-2001; and (ii) the non inauguration, or even non construction, of generation units present on the expansion plans, specially on the 1998-2007 plan.

B.1 Rationing Timeline

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

Feb-2000 The Priority Thermal Program (PPT) is created by the Ministry of Mining and Energy (MME) as the "unique solution" to a possible collapse of the system. This program aimed to increase the generation capacity of thermal power plants.

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 minimized the chances of any energy crisis during 2000-2003.[27]
Late-2000	ANEEL established criteria for the competitive process of additional power offers (capacity auctions) and determine that the spot market should buy 2500 MW of extra capacity.
Dec-2000	ONS points a better scenario for 2001 than the 2000's one, with no collapse of the system.
Feb-2001	Hydrological conditions reaches 70% of the long run average, and ONS radically change the forecast for 2001.
Mar-2001	ONS officially request the federal government a 20% load reduction (Nota Técnica ONS 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.[28]
May-2001	Government announces a six months rationing to be implemented in June.[29]
June-2001	Household restrictions are implemented.
Feb-2002	Household restrictions are withdraw.[30]

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[27] 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". The minister also stated that this condition would be satisfied with probability greater than 90%. (26/07/2000)

[28] "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 this 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 33 measures initially planned were implemented. (Folha de São Paulo, B7, 05/05/2001)

[29] 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).

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

C Statistical Appendix

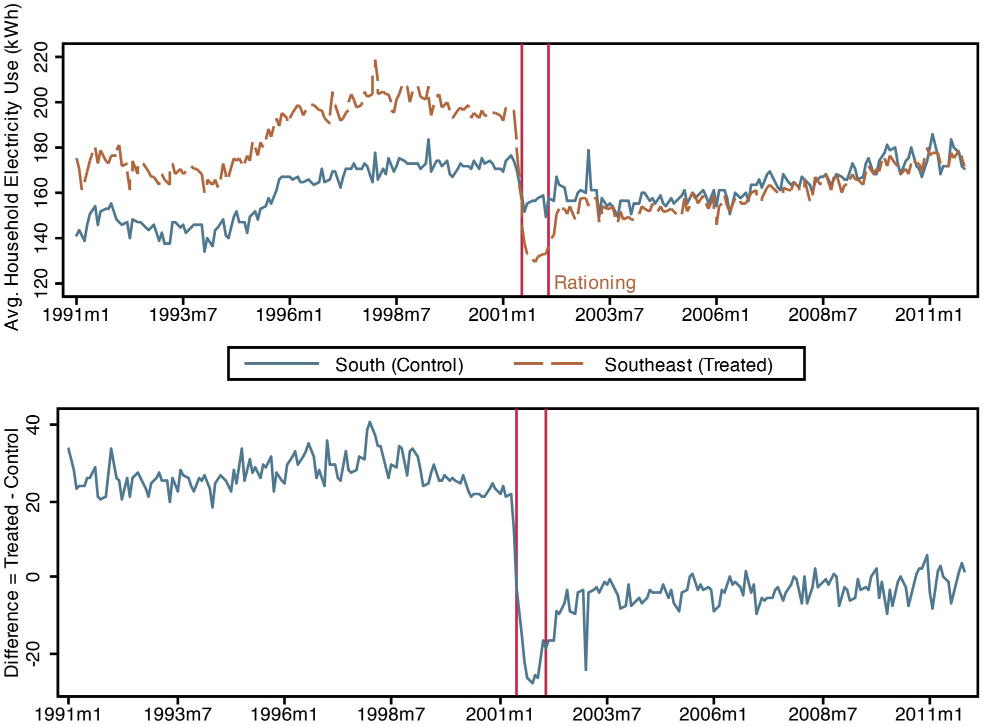

Figure C.2: Average Household Electricity Use (Season Adjusted, 1991-2011)

C.1 Baseline Tests and Covariates

Table C1 presents the results from the regressions testing mean equality of average electricity use in the two regions with different controls:

$$Y_{it} = \alpha + \beta Ration_i + \gamma X_{it} + \epsilon_{it} \tag{6}$$

where as before $Ration_a$ is a dummy equal to one if utility i was rationed and zero otherwise, and X_{it} is a vector of controls.

I test the parallel trend hypothesis by estimating the following OLS regression

Table C.2: Pre Rationing Mean Equality Test

	Dependent variable: Average Electricity Use Per Household (kWh)			
	(1)	(2)	(3)	(4)
Treated Region (β)	25.4**	25.0**	11.5	5.0
	(7.36)	(7.55)	(6.96)	(6.24)
Controls				
Electricity Price	.	✓	✓	✓
Real Wage	.	.	✓	✓
Temperature	.	.	.	✓
R-squared	.16	.16	.40	.43
Mean Dependent Var.	183.2	183.2	183.2	183.8
# Obs	1751	1751	1751	1666
# Clusters	43	43	43	43

Notes. This table displays the OLS estimates of equation (3) in Appendix C. The dependent variable is average household electricity use taken from the Electricity Regulatory Agency (ANEEL) balance sheet, which is at month-utility company level. Each column corresponds to a different regression, using the specifications indicated in the rows. Nominal electricity price and wage are from ANEEL and the Brazilian Ministry of Labor's register (RAIS) data sets, respectively. I compute prices and wages in real terms by dividing nominal variables by the Consumer Price Index (INPC/IBGE). Temperature is from the National Meteorology Institute (INMET). The *sample* spans from January 1998 until May 2001, including the 44 utility companies from the subsystems South, Southeast/Midwest. Standard errors are clustered by utility company. Regressions with constant. **p<.01, * p<.05, + p<.1.

$$Y_{it} = \alpha + \delta t + \delta_T Ration_i * t + \gamma_i + \gamma X_{it} + \epsilon_{it} \tag{7}$$

where δ capture the common time trend, δ_T the time trend specific to the rationed areas, and γ_i are utility fixed effects.

C.2 Triple Difference Specification

The Household Budget Survey contain households who own electric appliances but who claim to have no expenses on electricity. The electricity specialists in Brazil understand that these are households who steal electricity, popularly known as "cats". Since "cats" were not rationed, I use them as a second control group and perform a triple-difference estimation, as in Ravallion et al (2005). Then, I take one further difference to compare how payers and "cats" were differently affected in the two regions:

$$DDD = E\left[\left(Y^{SE}_{Post} - Y^{S}_{Post}\right) - \left(Y^{SE}_{Pre} - Y^{S}_{Pre}\right) | \, payer\right] - E\left[\left(Y^{SE}_{Post} - Y^{S}_{Post}\right) - \left(Y^{SE}_{Pre} - Y^{S}_{Pre}\right) | \, non-payer\right].$$

As mentioned in the text, this specification demands strong assumption about the evolution of these variables, specially regarding the long run effects.

Estimates presented in Panel B of Table 4 corresponds to the following regression equation:

$$Y_{iat} = \begin{array}{c} \alpha + \beta_D During_t * Ration_a * Payer_i + \beta_P Post_t * Ration_a * Payer_i + \\ +\alpha_{1D} During_t * Ration_a + \alpha_{1P} Post_t * Ration_a + \\ +\alpha_{2D} During_t * Payer_i + \alpha_{2P} Post_t * Payer_i + \\ +\alpha_3 Ration_a * Payer_i + \alpha_P Payer_i + \gamma_a + \\ +\gamma_D During_t + \gamma_P Post_t + \gamma_t t + \gamma_m + \gamma X_{iat} + \epsilon_{iat}. \end{array}$$

Table C.5 presents the results from the main difference in difference regression with a sample of non-payers only.

Table C.3: Pre Rationing Common Trend Test

	Log Electricity Use Per Household				Log Real Elect Price	Log Real Wage	Log Avg. Temp. (^0c)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
δ_T	-.001**	-.001**	-.002**	-.001**	.004**	.002*	.002*
	(.000)	(.000)	(.000)	(.000)	(.001)	(.001)	(.000)
δ	-.000	-.000	.001*	.000	.001	-.002**	-.002**
	(.000)	(.000)	(.000)	(.000)	(.001)	(.001)	(.000)
Area Fixed Effects	✓	✓	✓	✓	✓	✓	✓
Electricity Price	.	✓	✓	✓	.	.	.
Real Wage	.	.	✓	✓	.	.	.
Temperature	.	.	.	✓	.	.	.
R-squared	.88	.88	.88	.90	.60	.99	.40
# Obs	1751	1751	1751	1666	1751	44	1666
# Clusters	43	43	43	43	43	11	43

Notes. This table displays the OLS estimates of equation (4) in Appendix C. Each column corresponds to a different regression, with dependent variables in the columns and with the specifications indicated in the rows. Average household electricity use taken from the Electricity Regulatory Agency (ANEEL) balance sheet, which is at month-utility company level. Nominal electricity price and wage are from ANEEL and the Brazilian Ministry of Labor's register (RAIS) data sets, respectively. I compute prices and wages in real terms by dividing nominal variables by the Consumer Price Index (INPC/IBGE). Temperature is daily data for each weather station from the National Meteorology Institute (INMET). The *sample* spans from January 1998 until May 2001 and states from the South, Southeast, and Midwest. Wage data is annual for each state. Standard errors are clustered by area, which is utility company, state, or weather station according to the dependent variable. Regressions with constant and area fixed effects. **p<.01, * p<.05, + p<.1.

Table C.4: Covariates Averages and Regional Differences

	Before Rationing Difference = SE - S (1)		After Rationing Difference = SE - S (2)		D-i-D = (2) - (1) (3)	
Avg electricity use per household (kWh)	25.4**	(7.4)	2.0	(6.5)	-23.4**	(2.6)
# Households connected to the grid (1000)	478.0+	(277.7)	554.2	(342.2)	76.2	(88.1)
Share of households paying for electricity	-.02	(.02)	-.01	(.02)	.00	(.00)
Avg electricity price (R$/kWh)	.01**	(.00)	.01*	(.01)	.00	(.01)
Household price index (INPC, base 2001)	.01+	(.01)	.05*	(.02)	.04	(.02)
Electric appliance price index (IPC)	.01*	(.00)	-.05	(.06)	-.07	(.06)
Avg worker wage (R$)	67.0	(83.6)	185.8	(172.0)	118.8	(94.3)
Number of workers (million)	.46	(.92)	.59	(1.21)	.13	(.31)
Avg household size	.1	(.2)	.0	(.1)	-.1	(.1)
Avg temperature (^{o}c)	4.2**	(.6)	3.7**	(.6)	-.6**	(.2)
Share of days above 30^{o}c	.27**	(.06)	.23**	(.05)	-.03+	(.02)
Precipitation (mm)	-1.1**	(.2)	-.7**	(.2)	.5**	(.2)

Note: Standard errors clustered by utility/state/city level in parenthesis. Sources: ANEEL, POF, IBGE, FGV, RAIS, and INMET. Number of observations in order: 7291, 7291, 52820, 7291, 1169, 439, 143, 143, 52820, 219273, 111395, 107878, 227345, 222682. **p<.01, * p<.05, + p<.1.

Table C.5: Results on Appliances Holdings (Non-Payers)

	Refrigerator			Freezer			AC		
	Quantity	Vintage	New	Quantity	Vintage	New	Quantity	Vintage	New
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A. Difference in Differences (Non-payers)									
Rationing Effect in 2002	-.35	.02	.32+	-.36	.08	.09	.98**	1.24**	-16.6**
	(.40)	(.18)	(.18)	(.51)	(.72)	(.83)	(.09)	(.39)	(.53)
Rationing Effect in 2008	-.89*	.27+	-.03	-.49	.50	-.04	.08	2.03**	-17.3**
	(.41)	(.15)	(.31)	(.42)	(.59)	(1.16)	(.54)	(.61)	(.77)
Sample Mean	0.8	5.6	.12	.14	6.0	.10	.09	4.7	.11
R-squared	.06	.01	.01	.14	.02	.04	.26	.01	.05
Years	3	3	3	3	3	3	3	3	3
States	11	11	11	11	11	11	11	9	9
Observations	8506	6099	6099	8506	1299	1299	8506	367	367

Notes. This table displays the estimates of the rationing effects on the average stock of appliances, using micro data from the Household Budget Survey 1996/1997, 2002/2003 and 2008/2009 (POF/IBGE). It presents the results of a difference in difference estimation comparing households who do not pay for electricity in the South with non-payers in the Southeast/Midwest. Each column corresponds to a different dependent variable and appliance. *Quantity* means the number of appliances in the domicile. *Vintage* is the number of years since the appliance was bought, bunching all ages above 15 years old together. Regressions of these two dependent variables are estimated using ordered logit. *New* is a dummy variable equal to 1 if appliance was bought less than two years ago, and zero otherwise. 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 impact on the share of appliances bought during the rationing. Regressions of Vintage and New variables are *conditional* on appliance ownership. All regressions with state fixed effects, year fixed effects, income, number of household members, and a dummy for rural regions. Standard errors are clustered by state. All regressions use sampling weights. **p<.01, * p<.05, + p<.1.

C.3 Qualitative Variables

Tables C.6 and C.7 tabulates the responses from qualitative questions contained in the Appliances and Habits of Use (PPH) survey 2004/2005. Table C.6 gives some intuition on how the rationing affected the life quality of households from both regions, and in which extent people susbtituted incandescent light bulbs by flurescent 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.

Table C.7 present results on what households from the Southeast/Midwest did with their appliances after the rationing was over.[31] We see that a significant share of households started using less all appliances. Unfortunately, we cannot compare with the households in the South because they were asked only if they bought the appliance after the rationing.

D Results on Heterogeneous Effects

In this section, I examine potential heterogeneous responses to the rationing. Since I do not have panel data, I interact the treatment with the income quantiles to access how each income quantile was affected by the rationing. I present graphically the relevant coefficients of the following regression:

$$Y_{iat} = \begin{array}{c} \sum_{q=1}^{5} \left(\beta_{D,q} During_t * Ration_a * Q_q + \beta_{P,q} Post_t * Ration_a * Q_q\right) \\ +\alpha + \gamma_D During_t + \gamma_P Post_t + \gamma_{a,q} + \epsilon_{iat} \end{array} \tag{8}$$

where Q_q is a dummy for the q's income quantile, and $\gamma_{a,q}$ are area-quantile fixed effects.

D.1 Electricity Consumption Habits

Figures D.1 to D.5 present graphically the coefficients from regression (5) of the specifications in Table 3. We can see in Figure D.1 that the rationing reduced freezer utilization in all income

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[31] 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 C.6: 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 C.7: 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.

quantiles, particularly in the two lowest. As discussed in section 5, hours of use of air conditioners has large variance, but even so we see in Figure D.2 that the median income was the only who significantly reduced air conditioner utilization.

Figure D.3 presents the coefficients on hours of use of light. It shows that the hours of use of lamps of the top income quantile was the only not affected by the rationing. In particular, it suggests a stronger change by the two lowest income quantile.

Figures D.4 and D.5 present the rationing effects on electric shower thermostat and adoption of energy-saving measures. We can see that, despite the large confidence intervals, the rationing affected all income quantiles.

D.2 Electrical Appliances Holdings

Figures D.6 to D.8 present graphically the coefficients from regression (5) of the difference in difference specifications in Table 4, Panel A. Figure D.6 shows that, in 2002/2003, the average refrigerator became older in the Southeast/Midwest relative the South across all income quantiles. Although not all significant, it shows that refrigerators became more likely to be New in the rationed states than in the non-rationed states. It shows as well that the rationing had no effect on quantity and vintage by 2008/2009.

Figure D.7 show results regarding freezers. It shows that the top income quantiles reduced the quantity of freezers at home due to the rationing, with effects lasting until 2008/2009. Interestingly, we find no effect on appliances vintage. At last, Figure D.8 shows that the average air conditioner became relatively older in the Southeast/Midwest across all income quantiles.

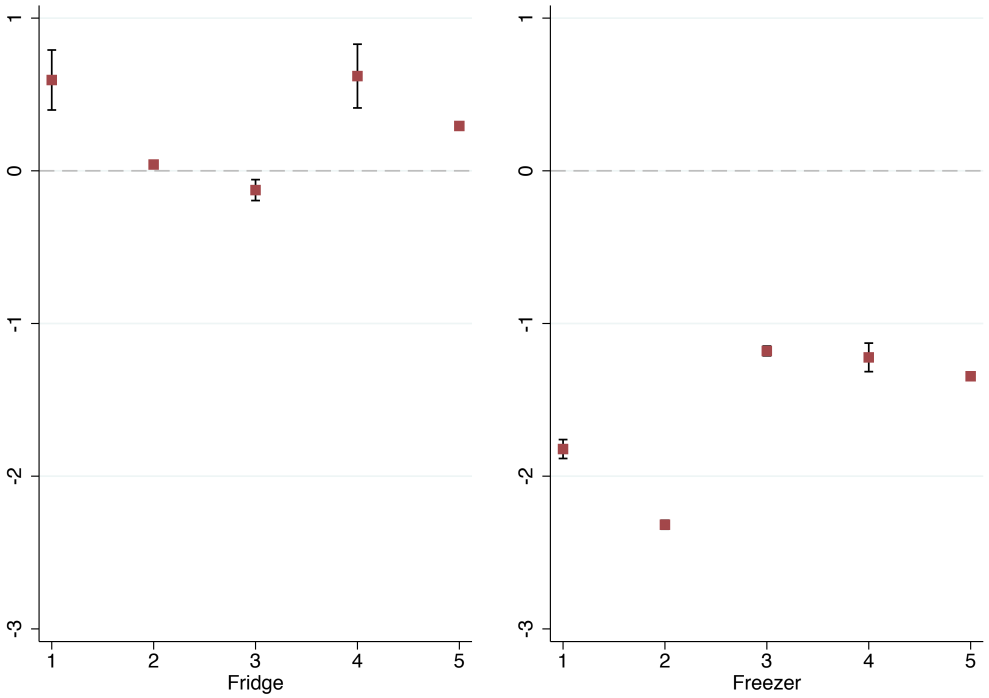

Figure D.3: Appliances In Permanent Use (Table 3, Columns 1-2)

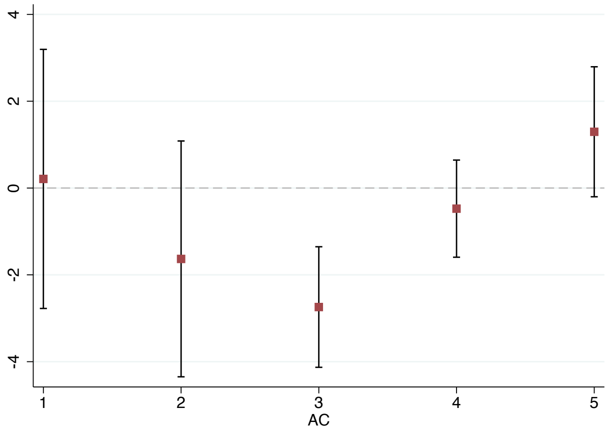

Figure D.4: Hours of Use of Air Conditioners (Table 3, Column 3)

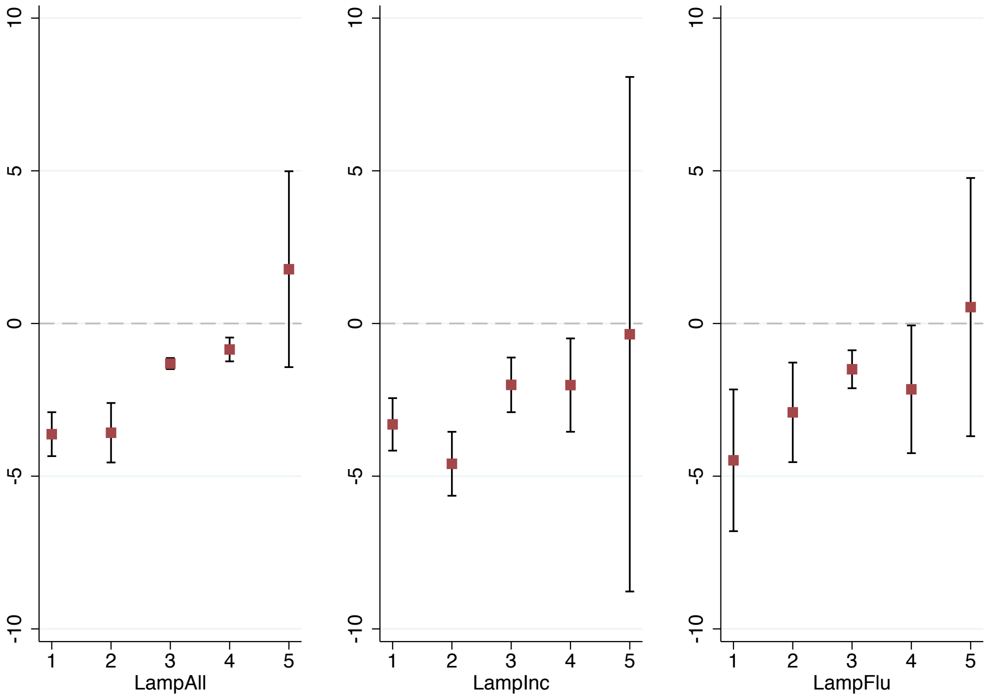

Figure D.5: Hours of Use of Lamps (Table 3, Columns 4-6)

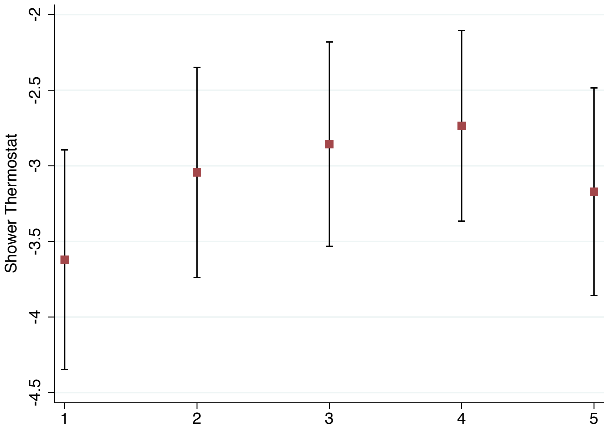

Figure D.6: Electric Shower Thermostat (Table 3, Column 7)

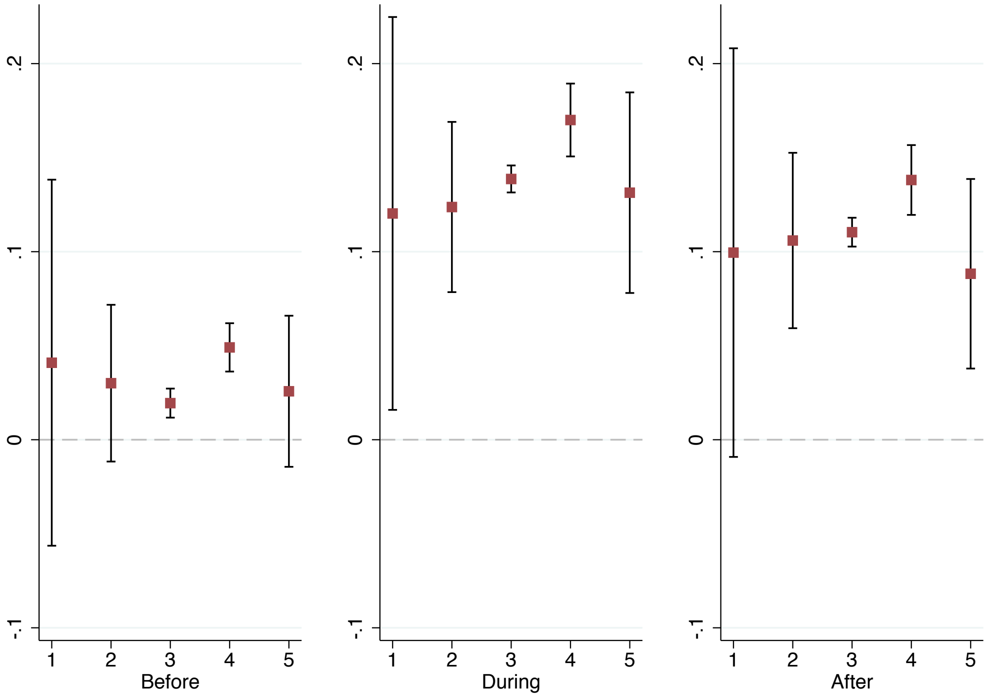

Figure D.7: Adoption of Energy-Saving Measures (Table 3, Columns 8-10)

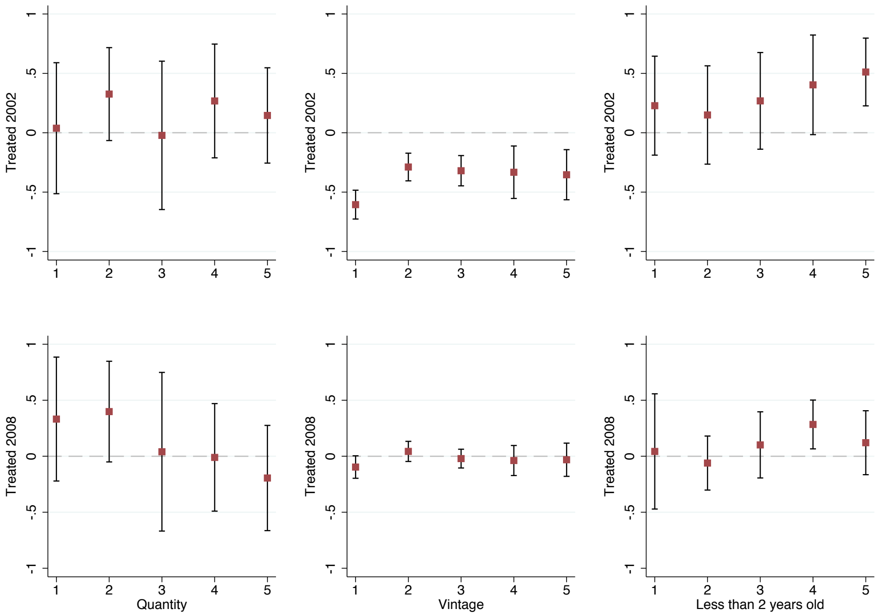

Figure D.8: Refrigerator (Table 4, Panel A, Columns 1-3)

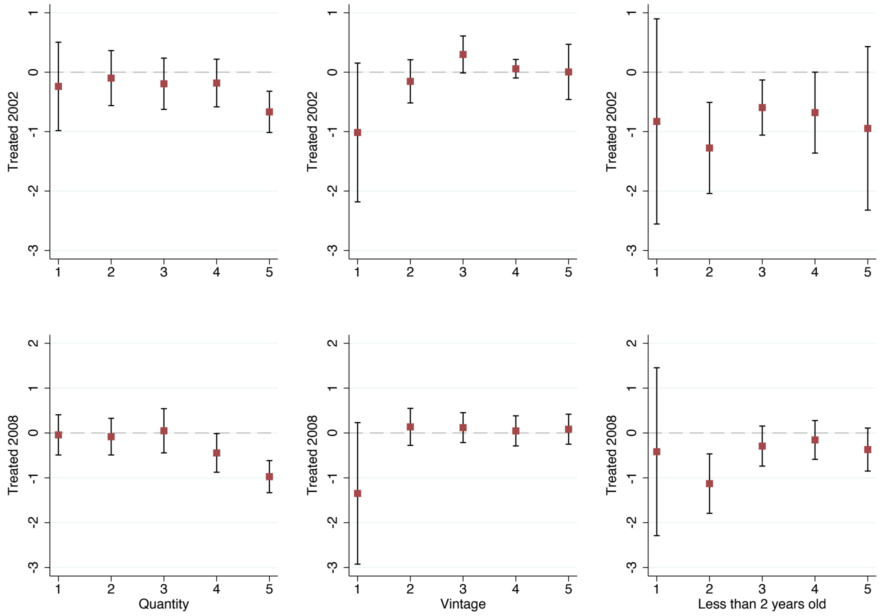

Figure D.9: Freezer (Table 4, Panel A, Columns 4-6)

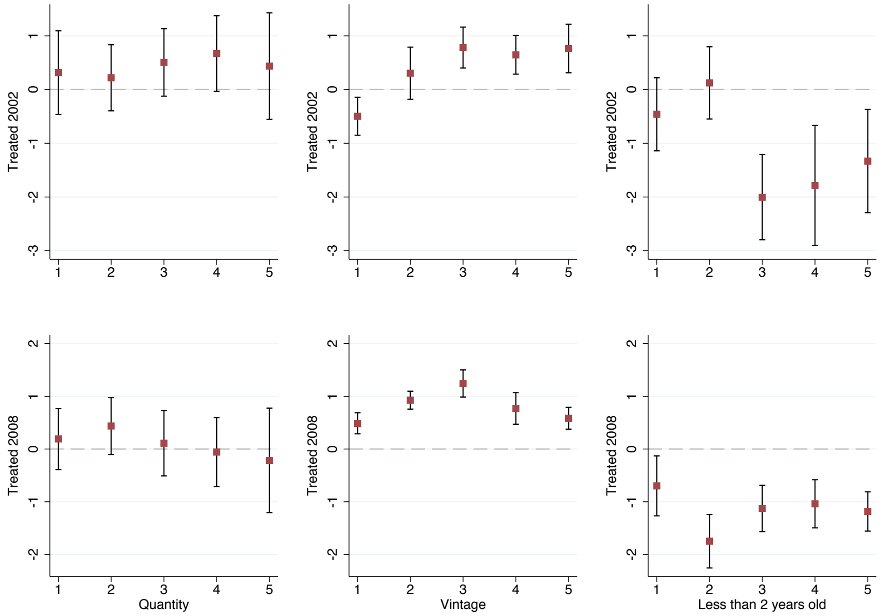

Figure D.10: Air Conditioner (Table 4, Panel A, Columns 7-9)