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Prepaid electricity and in-home displays: an alternative for the most vulnerable households in Colombia

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Prepaid electricity and in-home displays: an alternative for the most vulnerable households in Colombia*

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Abstract

Exploiting the implementation of a Prepaid Electricity Program in the Department of Antioquia (Colombia), I estimate the impact that switching to this kind of programs has on users' energy consumption behavior, with particular emphasis on those that are more vulnerable from a socio-economic point of view. I find that the new scheme and the information provision is associated with a decline in electricity consumption of 15.04%, in aggregate. However, the magnitude and the direction of this effect will depend on whether the user exhibited or not overconsumption before the switch. This scheme allow users to improve their consumption paths, while their access to public electricity services is guaranteed, minimizing disconnection risks and the associated costs.

Keywords: Prepaid schemes, In-home displays, Electricity consumption, Smart meters, Energy efficiency.

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1 Introduction

There is a growing awareness of the need to expand infrastructure and improve technology to provide energy, mainly in developing countries, given the increasingly rapid evolution of electricity consumption. Since the beginning of the 21st century, global electricity consumption has experienced faster growth, evidenced by an average annual increase of 3.4% (Liu, 2016). Regarding the Colombian context, the country doubled its electricity consumption of 1998 in 20 years, reaching 69 TWh[1] [2] in 2018, according to the Global Energy Statistical Yearbook of 2019. Furthermore, energy efficiency strategies has been recognised as an essential element of the European Union's energy and climate change mitigation policies (Podgornik et al., 2016).

Besides, it is widely acknowledged that access to modern energy services is a prerequisite for the economic and social development of populations in developing countries (Tenezakis and Tritah, 2019), and that low-income households face difficulties in guaranteeing their connection to electric power services. Therefore, there is a need to develop and implement new approaches, regulations and technologies that allow a better understanding of the energy use of households and encourage its responsible and efficient use, while guaranteeing access to those segments of the population that do not have a stable flow of income over time and have some uncertainty when paying their obligations.

Smart metering and various consumption-feedback systems have been used as applicable technology to encourage energy efficiency in the residential sector (Podgornik et al., 2016). In addition, numerous studies have documented the influence of electricity prepayment schemes on household energy consumption behavior and its possible use as a solution to the non-payment problem among low-income households (Tewaria and Shah, 2003; OSullivan et al., 2013; Jack and Smith, 2015; Azila-Gbettor et al., 2015; Qiu et al., 2016; Nugrohoa et al., 2017). These types of programs have been used in more than seventeen countries (see Telles-Esteves et al. (2016) for an overview of electricity prepayment experiences). In general, they consist of four components: the electricity meter, vending points, a communication unit, and a central server (Telles-Esteves et al., 2016). In most cases, an in-home display accompanies the prepaid meter (Qiu et al., 2016), providing direct feedback as real-time information on energy consumption and credit availability.

Although these types of prepaid electricity schemes have been implemented throughout the world during several years, and there is some evidence about its effects on energy consumption, the literature lacks more reliable causal estimates of the effect of these prepaid schemes on household energy consumption behavior, except for the work done by Qiu et al. (2016). In this paper, I exploit the implementation that *Empresas Públicas de Medellín* (EPM henceforth, by its acronym in Spanish) has been carrying out of a prepaid electricity program since 2005 to date, focusing my analysis on the period of time between January 1, 2007 and December 31, 2017, due to data constraints. I estimate the causal impact of being part of the program on electricity consumption.

[1] One teraWatt hour is equivalent to 1 billion Watts hour or one thousand million kilowatts hour.

[2] According to *Empresas Públicas de Medellín*, a household with four members consumes, on average, 152 kWh, each month.

I attempt to asses the potential improvements in energy efficiency derived from the implementation of this scheme. This research gives evidence on possible efficiency gains for households that are part of the prepaid scheme, with special emphasis on vulnerable population. My results suggest that low-income users, due to the information provided in the new scheme, reduce their overconsumption by tracking their energy use.

EPM's prepaid electricity program is a social innovation initiative in the Colombian and Latin American context that seeks that the provision of electric service adapts to the dynamics of household income. In order to do so, this program offers the provision of electricity service under a prepaid scheme to those families who, due to adverse conditions, are liquidity constrained and have limited electricity access. Moreover, using double-part meters with in-home displays providing real-time feedback, the consumer receives much more information. This additional information could help the consumer to manage better his electricity usage (Jack and Smith, 2015; Podgornik et al., 2016) and generate energy savings that benefit him (Faruqui et al., 2009), while the utility reduces the overdue portfolio.

This initiative is particularly relevant in the Colombian context. The Colombian State developed, at the end of the last century, redistributive transfer schemes that seek, in a certain way, to guarantee access to essential public services by vulnerable households. In short, the Colombian utilities pricing system uses a cross-subsidy scheme between households. It rests on a strata based system, which allows households with better incomes economically assist the most vulnerable population, aiming to achieve universal coverage (Bonilla et al., 2014). However, the stratification mechanism nowadays shows rigidities in responding sustainably to an increasingly dynamic and complex national environment, and is subject to severe problems of missclassification. Moreover, the tariff subsidies offered to low-income households do not guarantee that they can pay their obligations with the utilities every month.

There is an obstacle to identify reliable causal estimates of the effect of the prepaid program: the application to the program is entirely voluntary, and households wishing to have prepaid electricity must file a format requesting the service, which generates a self-selection problem. Furthermore, due to data constraints, I do not have access to those who were eligible for the program but never accessed it. I do not have access either to the data of the non-eligible households. In other words, I do not have any untreated units in my research design. I tackle the self-selection issue exploiting the fact that users must meet some socio-economic requirements and have had some suspension problems to be eligible for the progam. Therefore, it is plausible to assume that the prepaid scheme adoption occurred within different municipalities at different points of time and, those adoptions were uncorrelated with levels and pre-treatment trends in consumption, conditional on being eligible for the progam. In addition, as I do not have untreated units, I exploit the variation in the adoption timing to create treatment and control groups at different points in time, based on the changing in the treatment status.

Within this strand, I propose to use a Difference-In-Differences (DiD) setting with staggered adoption, exploiting the differences when users decided to switch and adopt the prepaid scheme, to assess the effects of the program on energy consumption behavior. I use two different data sources from the prepaid electricity program provided by EPM: a database with information on monthly electricity consumption, billing, and certain variables that allow me to characterize the household in geographical and socio-economic terms between January 1, 2010, and December 31, 2017. Additionally, I have a subsample of that first database containing information on additional variables for the period between January 1, 2013, and December 31, 2017. Among these new variables of interest are the amount of outstanding debt with EPM, the value charged in each carriage, and the payment of other services such as trash collection and sewer. Unfortunately, I could not join both databases due to information restrictions.

I obtain several results. My semi-parametric approach allows me to retrieve a decrease of 15.4% in monthly electricity consumption. Compared to the average user consumption in the sample before the switch, this drop represents a reduction of 20.88 kWh/month. This result is maintained, regardless of whether the household exhibited any type of suspension before the switch. Nevertheless, when I divide the sample among those households that presented overconsumption before the switch and those that did not, I find two conflicting results. Dwellings of strata 1, 2 and 3, that exhibited overconsumption before the switch, reduced their consumption outside the subsidized range in 46.69%, but dwellings of strata 1, 2 and 3, that did not exhibit overconsumption before the switch, increased their electricity consumption in 23.9%.

This paper relates to a large body of literature that studies household energy consumption behaviour (e.g., Faruqui et al. (2009); Lopes et al. (2012); OSullivan et al. (2013); Gans et al. (2013); Jack and Smith (2015); Azila-Gbettor et al. (2015); Qiu et al. (2016); Nugrohoa et al. (2017)), energy affordability (e.g. Casas et al. (2005); Santa-María et al. (2009); Bonilla et al. (2014); Piai-Paiva et al. (2019)), energy efficiency and its policy implications (e.g. Tewaria and Shah (2003); Telles-Esteves et al. (2016)).

The rest of the paper is organized as follows. In the next Section, I provide some context about the program and its implementation. Section 3 describes the main sources of data and provides some descriptive statistics. In Section 4, I present the identification strategy and the methodology. Section 5 presents the paper's key results on the impact of being part of the program on electricity consumption, while Section 6 tests evaluate various alternative explanations of the results. Section 7 concludes. Additional results and robustness checks are provided in a separate appendix.

2 Context of the program

According to the National Competitiveness Report for 2018-2019, the Mining-Energy Planning Unit (UPME, by its acronym in Spanish) points out that the projection of Colombia's electricity demand to 2032 could be 58.5% higher than the current one. Moreover, between 2023 and 2032, it is necessary to incorporate new electricity generation projects, since the supply would be insufficient in 2026.

According to Núnez et al. (2011), in 2008, in the group of households of strata 1, 2 and 3 in Medellín, 4.16%, 3.03% and 1.9% of them, respectively, had a suspension[3] in at least one of the domiciliary public services. Furthermore, communes[4] such as Manrique, Popular, Santa Cruz and Doce Apostoles, neighborhoods located on the outskirts of the city, concentrated the most significant number of households with arrearage debts, according to the 2008 Quality of Life Survey for Medellin (Núnez et al., 2011).

These patterns, prevailing even before 2008, motivated EPM to extend to vulnerable households an initiative that, in alliance with the government of Medellín, sought to improve the relationship between the utility and commercial electricity users in the center of Medellín, mainly informal sellers. After a feasibility study and a pilot test between 2005 and 2006, with the participation of 94 residential dwellings, EPM decided to roll out in 2007 the *Prepaid Electricity Progam* with defined coverage (the program henceforth). This program sought that users of electric energy self-manage their consumption and enable them to consume according to their payment possibilities without affecting their budget. This program was designed to fullfil the need of the low-income population to have access to energy services.

To achieve this goal, the program was designed its first stage for residential users of strata 1, 2, or 3 that were located only in the municipality of Medellín that, as of June 13th, 2007, had the service suspended or cut due to non-payment. For the context, users of strata 1, 2, or 3 are those that live in residences with below-par infrastructure conditions. These strata groups allow entities of different levels of governance to characterize their socio-economic conditions and target social public policy. One relevant example of these is the cross-subsidy scheme applied to the utility pricing system established in 1994. Figure 1 displays a simplified scheme of this tariff system based on strata.

Besides, residential users that were paying debts that include electricity consumption, through some financing programs offered by EPM, could request the change to the program, like those users who participated in the pilot. The objectives of the program were to provide users with more significant benefits and, at the same time, to improve and facilitate the management of non-technical losses of the utility due to late payment or illegal connection (Decree 1633 of 2007).

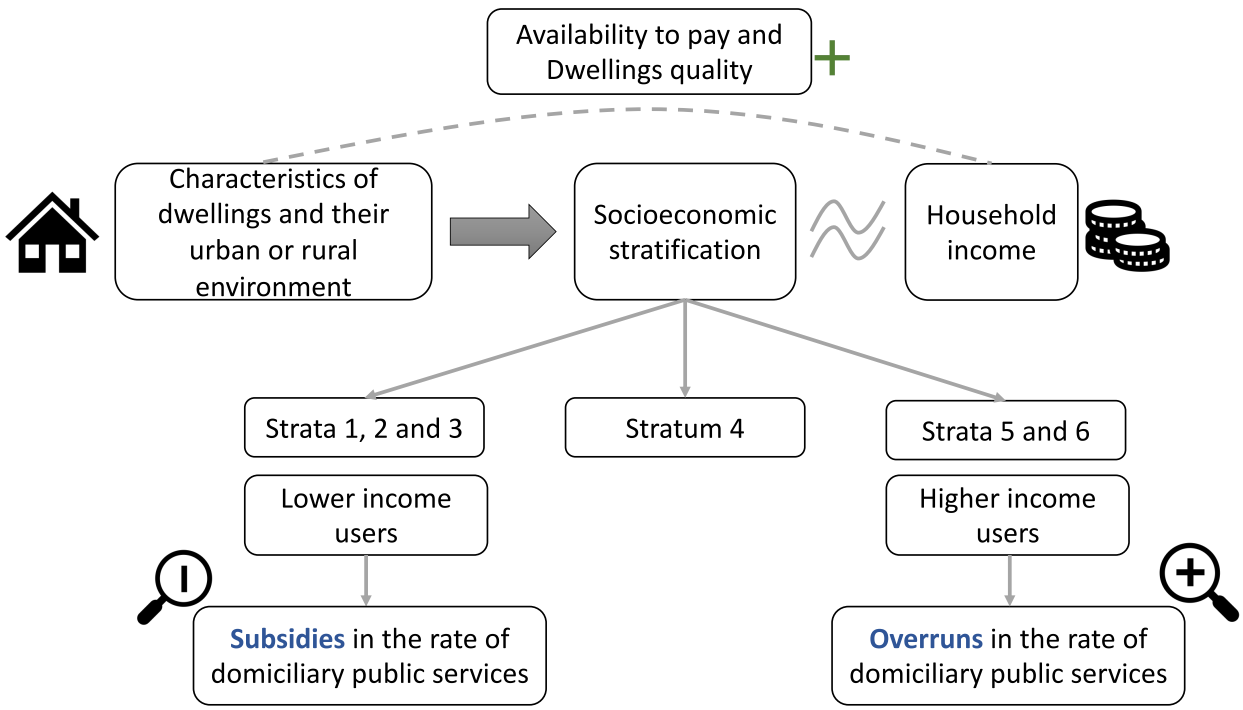
Although this program initially was conceived as a program that would last only one year, in November of 2007, the coverage was extended to all the municipalities of Antioquia that belonged to the EPM coverage area[5] (Decree 1643 of 2007). In September of 2008, the EPM Board of Directors

[3] Temporary loss of service keeping the contract of uniform conditions with the utility, generated by a delay in the payment of invoices between 2 and 7 months.

[4] A commune is an administrative unit in which the urban area of a medium-sized city or a principal city of Colombia is subdivided. Medellín has 16 communes, which contain the 275 official neighborhoods of the city.

[5] In 2018, EPM reached a coverage of 97.3% of the residences in the department of Antioquia, for the urban and rural sectors.

Figure 1: Stratification and Domiciliary Public Services



Notes: Own elaboration.

authorizes the enlargement of the program[6], in order to include 195,000 new clients until December 31, 2011 (Decree 1767 of 2010). Furthermore, since July 26, 2010, until December 31, 2011, the target market changed and users who, on the first calendar day of each month, had more than two suspensions or four consecutive months of suspension during the last twelve months, could access the program.

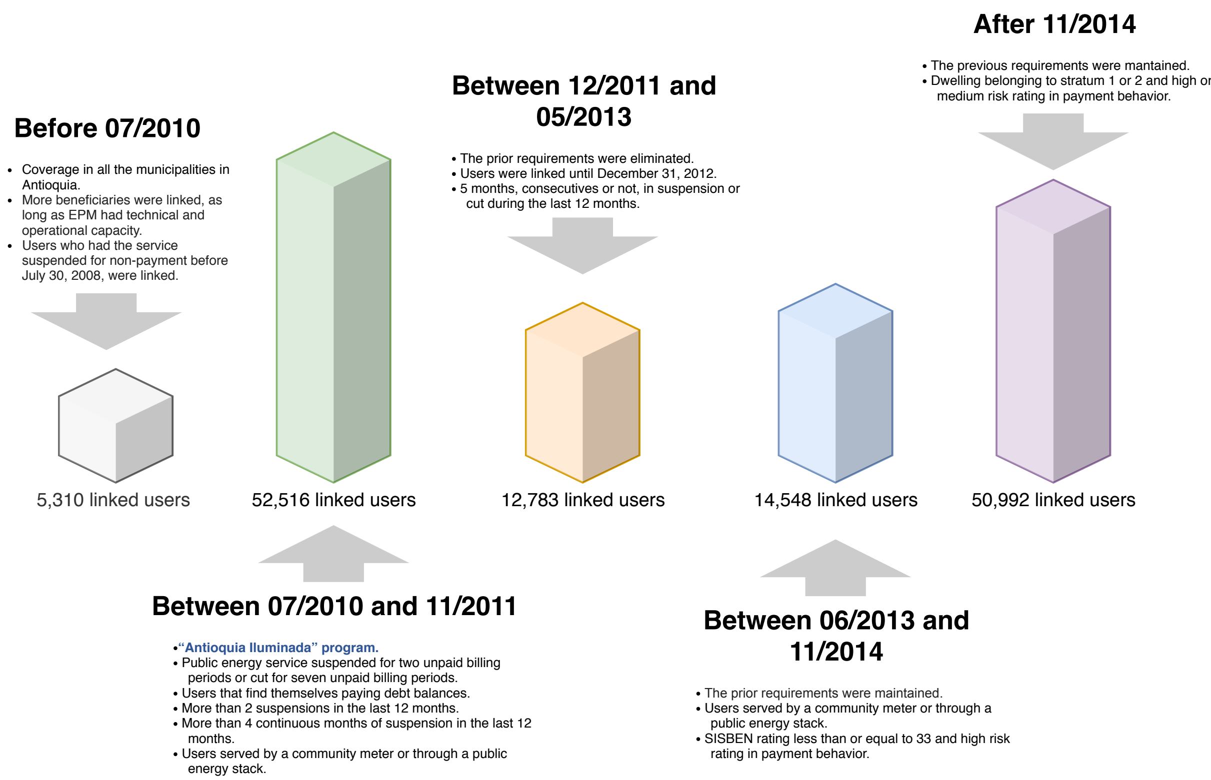
To date, four additional modifications have been made to the program regimentation, as can be seen in Figure 2. In 2011, the affiliation of new users was extended until December 31, 2012, and the target users were redefined to users who, at the time of requesting the service, presented at least five months, consecutive or not, of suspension or cut (Decree 1857 of 2011). In 2013, the coverage of the program expanded until the end of the *Antioquia Iluminada* program and, among the characteristics of the target market, was included a SISBEN[7] score of less than 33 and a high-risk rating in the payment behavior with the utility (Decree 1939 of 2013). In 2014, all the prerequisites for being part of the target market were maintained, and the condition that the dwelling must be of stratum 1 and 2 is included (Decree 2046 of 2014). Finally, in 2018, the goal of covering 18,550 vulnerable households or those in extreme poverty was fulfilled. Therefore, the additional conditions to be part

[6]This extension is authorized by linking the prepaid energy program to the *Antioquia Iluminada* program, which had a financing of 96,000 million pesos.

[7]Identification System of Potential Beneficiaries of Social Programs.

of the target market included in decrees 1939 and 2046 were removed (Lineament 27 of 2018).

Figure 2: Definition of the target market of the program



Notes: Own elaboration.

The affiliation to the program is subject to economic and technical feasibility[8] defined by EPM, and the users had to request the transfer to the prepaid service by themselves. When some user requests the switch to the prepaid scheme and is eligible to be part of it, he receives a prepaid double-part meter with an in-home display in bailment. The installation of the new meter and the disassembly of the post-payment meter is entirely free. The prepaid meter consists of a keypad meter in which users types an alphanumeric pin code, which is generated every time the user makes a recharge at a certified point of sale (see Figure A.1). In 2016, were approximately 34.135 recharging points in Antioquia, and, since 2015, EPM implemented a program called *Pre-carga*, which allowed users to make purchases through text messages. The prepaid meter also has an in-home display, which allows the user to visualize the identification number of the meter, the total electricity accumulated to date, the available credit, and more.

Users[9] in the prepaid scheme have the possibility of recharging from 2000 pesos onwards, bewteen

[8]For example, EMP takes some precautions when approving the prepaid scheme to a new user such as verifying that there is no person with a particular medical condition that requires energy permanently, due to dependence on some medical equipment.

[9]The average nominal minimum wage between 2010 and 2017 was 611,790 Colombian pesos.

2007 and 2012, or 3000 pesos onwards, from 2013 and later, if they are of stratum 1, 2, or 3. Ten percent of each recharge goes to pay outstanding debts with EPM, if they have any. The fee per kWh that users pay is the same as in the postpaid scheme, and the subsidies apply according to the CREG[10] regulation. On average, between 2010 and 2017, a user of stratum 1 had the benefit of a subsidy equivalent to 58.61% of the fee per kWh. Users of stratum 2 had a subsidy of 48.26% and users of stratum three at a subsidy rate of 15%. These subsidies apply over a specific range of consumption. For municipalities located at a height not exceeding 1000 meters above sea level, this range goes from 0 to 130 kWh. For municipalities located at a height greater than 1000 meters above sea level, this range goes from 0 to 170 kWh. The kWh consumed outside these ranges are charged at the full rate.

The users who made the switch to the prepaid scheme had some support by EPM staff about the use of the new scheme, the new meter and about efficient energy consumption strategies. According to EMP staff, these apprehension processes have been a fundamental part of the program's success. In December 2017, there were 230,917 users linked to the EPM prepaid energy program, distributed in the 128 municipalities of Antioquia and Córdoba, the area of influence of this utility. Currently, the program has also been implemented in the Santander and Norte de Santander Departments, whose electrification utilities are part of the EPM business group.

3 Data

Since the rollout of the program was in 2007, but I only have information about users since January 1, 2010, I restrict my sample to those users who made the switch to prepaid scheme in the observation period 2010- 2017, considering that I require information on the behavior of their consumption before the switch. Additional to information on electricity consumption, I also have information of billing and certain variables that allow me to characterize the dwellings in geographical and socio-economic terms. This study covers 136,534 dwellings in 128 different municipalities. The dynamic of the monthly switchings is displayed in Figure 3. Of these dwellings, 69,523 are of stratum 1, 54,438 of stratum 2 and 11,786 of stratum 3. 787 dwellings, 0.57% of the sample, are of stratum 4, 5, and 6. [11]

The period between June 2010 and December 2011 covers the largest number of transfers to the program: 52,516 residences adopted the prepaid scheme in this period of time. This can be explained due to the funding obtained from the *"Antioquia Iluminada"* program, allowing EPM to purchase new meters.

Figure A.2 shows the smoothed distributions of the electrical consumption for strata 1, 2, and 3 in the postpaid and prepaid schemes. Given the presence of some extreme values, a trimming of 1%

[10] CREG resolutions 096 of 2004 and 042 of 2012. CREG, by its acronym in Spanish, means Energy and Gas Regulation Commission

[11] According to EPM, the inclusion of dwellings of strata 4, 5, or 6 was due to difficulties in the programs' implementation, since these are not classified as low-income population.

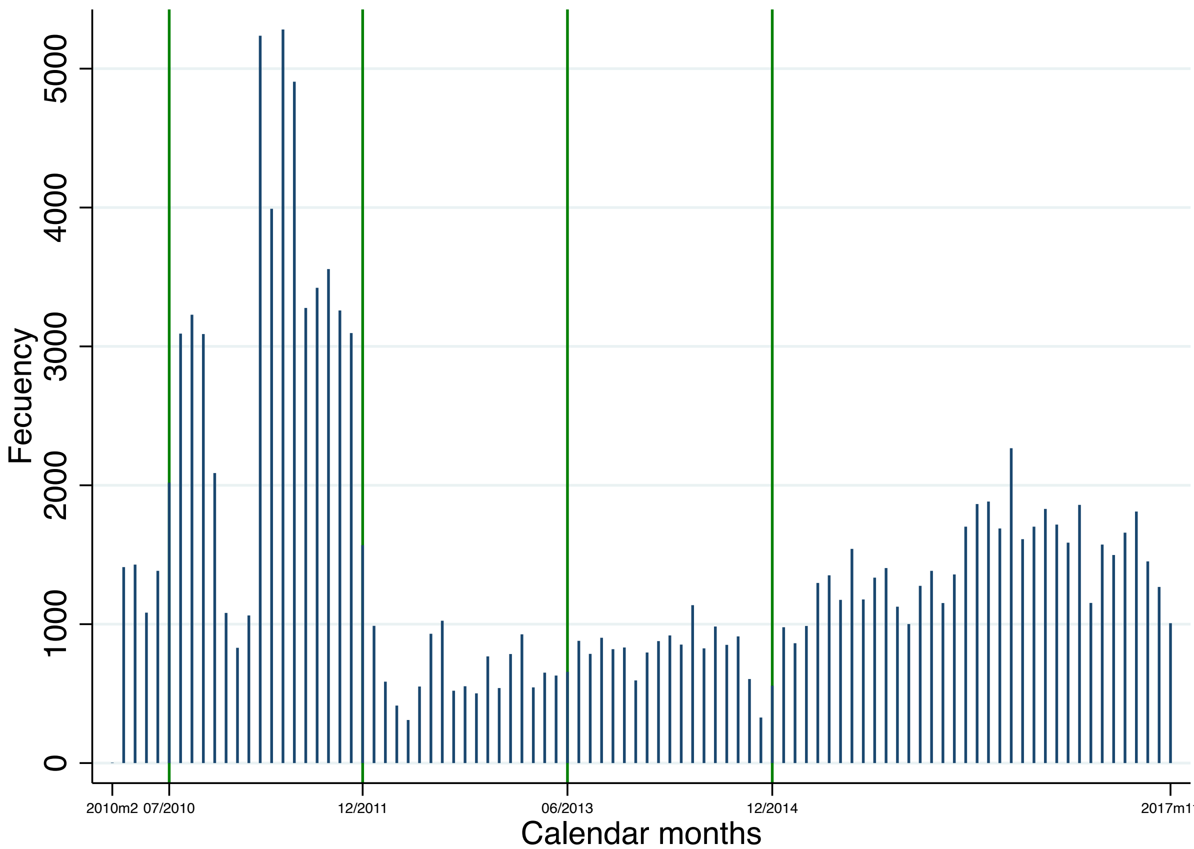


Figure 3: This Figure represents the number of swithings per month in all municipalities. The green lines represent the months in which new regulations were issued by EPM. Time period: 01/2010 - 12/2017.

is made in both tails of the distribution for this Figure and, for the estimates, I use the logarithm of the electricity consumption. As can be seen in the vertical axis of both panels of Figure A.2, there is a higher accumulation of users who consume a lower level of kWh/month in the prepaid scheme than in the postpaid scheme. Moreover, Figure 4 displays the number of switched users between 2010 and 2017 per 1,000 population, and Figure A.3 illustrates a heat map indicating the number of switched users between 2010 and 2017. As can be seen in Figure A.3a, Medellín concentrates the most significant number of switchings and users in the prepaid scheme: to 2017, a total of 55,514 new users switched to the prepaid scheme.

Figure A.3b illustrates a heatmap for all the municipalities of Antioquia, excluding Medellín. As it can be seen, the municipalities located in the north of the department, excluding Medellín, Bello and Itaguí, concentrate the largest number of switched users for the period of analysis. This is partly explained by the fact that they have larger populations (*i.e.*, most of them are among the 20th most populated municipalities of the department). Once controlled by the population size, the coverage of the program has been relatively homogenous throughout the department, as can be seen in Figure 4.

4 Methodology

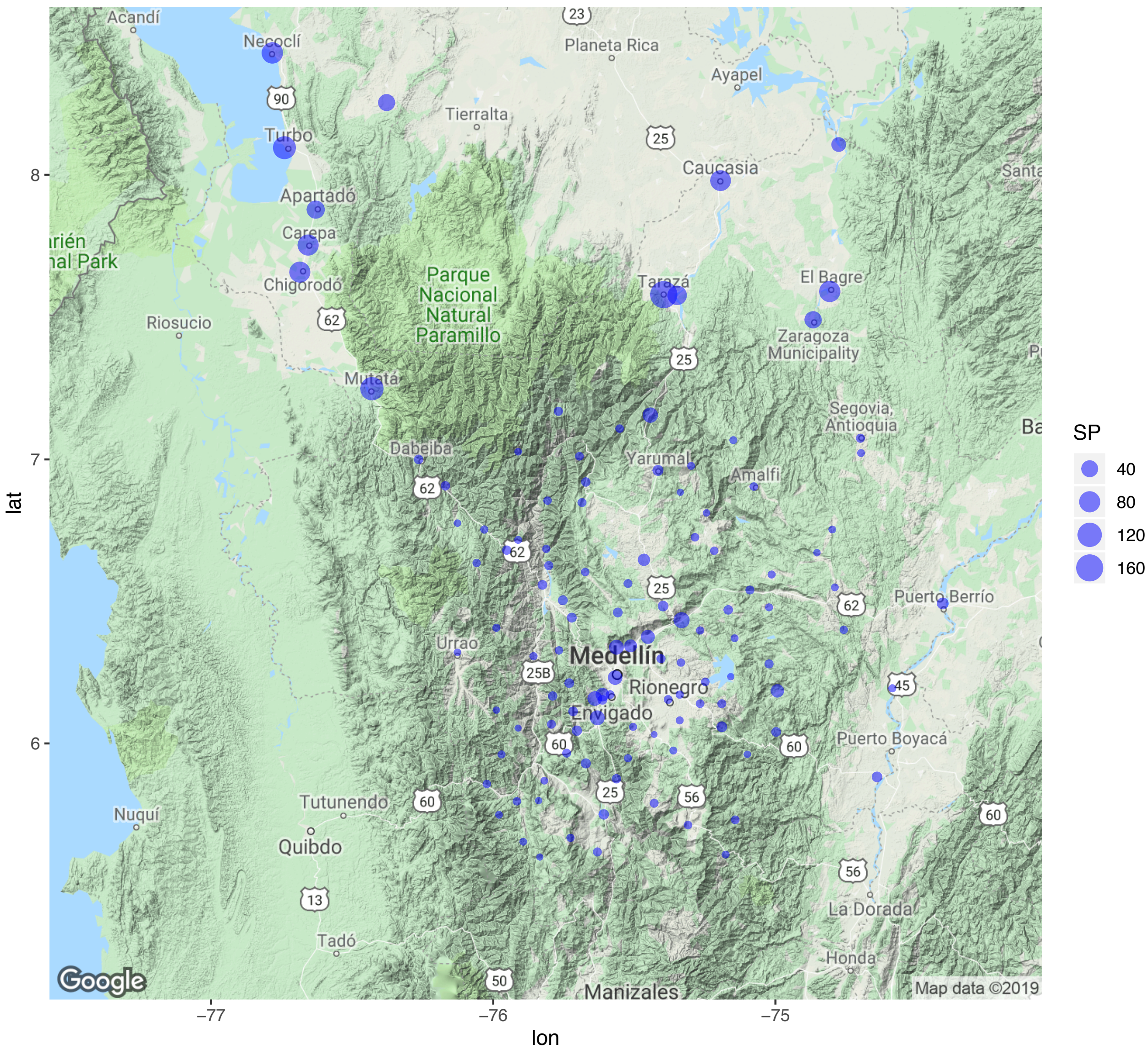
In this study, I aim to estimate the causal impact on the electricity consumption of switching to the prepaid electricity program. However, the application to the program is entirely voluntary, and users wishing to have prepaid electricity must file a format requesting the service, which generates a self-selection problem. To address this self-selection problem, I use the fact that households must meet some requirements, described in Section 2, to be part of the program's target market. The main assumption of my identification strategy is that the timing of the switch is not correlated with levels or trends in household consumption, electricity infrastructure or other observables (conditional on being eligible for being part of the target market). However, the eligibility criteria are correlated with household's socio-economic characteristics. Therefore I restrict all estimates to the set of households that are part of the program and that are available in the data provided by EPM.

Since households request the switching at different points in time, my main estimation equation for the results in this paper is the Difference-In-Differences with staggered adoption design (McCrary, 2007; Borusyak and Jaravel, 2017; Abraham and Sun, 2018; Higgins, 2019), as specified in equation 1, wich accommodates the varying of treatment and dynamic treatment effects over time.

$$c_{dt} = \alpha_d + \alpha_t + \alpha_{mt} + \sum_{j=-10}^{j=-2} \delta_j + \sum_{j=0}^{j=12} \delta_j + \varepsilon_{dt} \tag{1}$$

The main outcome of interest is the logarithm of the electricity consumption measured in kWh c_{dt}, where d and t stand for dwelling and month, respectively. The parameter δ_j, in equation 1 captures the relative event time indicators. That is, δ_j is an indicator variable taking value one if

Figure 4: This Figure represents the number of switched dwellings per 1000 population between 2010 and 2017.



it is the month j relative to the switching month, either before or after. The estimation equation includes dwelling fixed effects α_d to capture arbitrary time-invariant heterogeneity across dwellings within and between municipalities, and time fixed effects α_t to capture overall time trends. For some exercises, I include municipality-time fixed effects to capture heterogeneity across municipalities that vary across time, such as weather conditions or some aspects of the electrical infrastructure in each municipality. The disturbance term ε_{dt} represents standard errors clustered at the dwelling's level (Bertrand et al., 2004).

I create a set of treated and never treated residencies at different points in time by period. Then, within the same calendar months, I compare the electricity consumption of residencies that switched in a month t to those who decided to switch in a month $t+\delta$. This fully dynamic specification allows us to capture the dynamics of the electricity consumption relative to the month of the switching. I include ten months before switching and 12 months after switching. Furthermore, taking into account what was raised in Borusyak and Jaravel (2017) about the identification of the linear component of the path of pre-trends and dynamic treatment effects in the presence of unit and time fixed effects and, as in most event study specifications (*e.g.* (McCrary, 2007; Higgins, 2019)), I do not drop observations that are further than 10 months before or 12 months after the shock, but rather bin these by setting $\delta_{-10} = 1$ if $j \leq -10$ and $\delta_{12} = 1$ if $j \geq 12$.

In addition, the parametric specification allows us to analyze the statistical significance and magnitude of the estimates. I estimate the following specification:

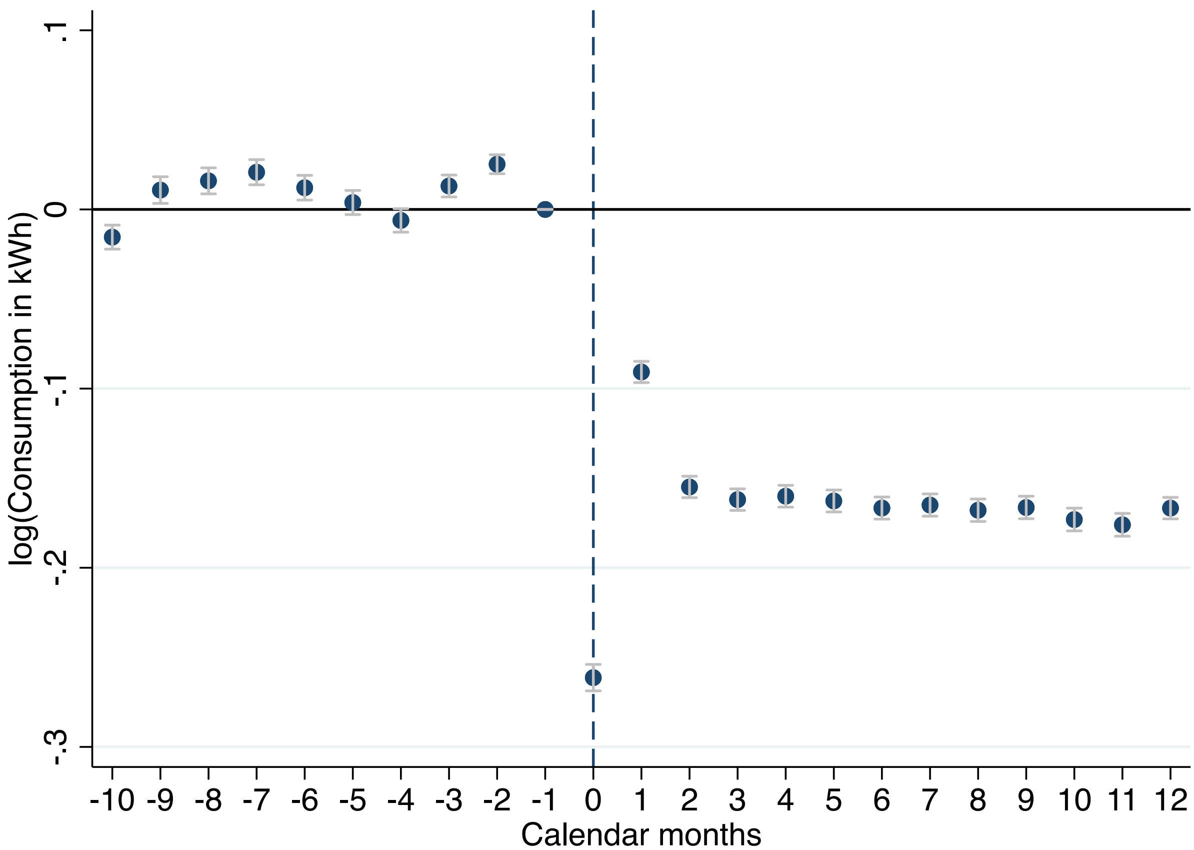
$$c_{dt} = \alpha_d + \alpha_t + \alpha_{mt} + \beta \text{PostPrepaid}_{dt} + \varepsilon_{dt} \tag{2}$$

Where d and t stand for dwelling and month, respectively, and **PostPrepaid** is an indicator variable taking the value 1 for all months after the switching and o for all the observed months in which the user was in prepaid scheme. The parameter β measures the changes in electricity consumption of the switched dwellings compared to the yet-to-be switched dwellings, conditional on the set of dwelling, month, and, for some exercises, municipality-month fixed effects.

5 Results

I begin by studying the impact of switching to the prepaid scheme on electricity consumption. I first explore the dynamics of the effects around the month of switching by estimating equation 1. I estimate this specification for both the complete sample and for two subgroups: those users who presented suspension or cut before switching to the prepaid scheme and those users who presented regular consumption. Figure 5 displays the point estimates of the non-parametric difference-in-differences with staggered adoption specification over the window of 10 months before and 12 months after the switch. The Figure 5 illustrates the impact of the switch on the electricity consumption behavior. After the switch, I see a decrease in monthly electricity consumption. The effect takes place the month following the switch and is persistent over time.

Figure 5: Effect of switching to the prepaid scheme on user's electricity consumption I



This Figure shows the coefficients from equation 1, where the outcome variable is the electricity consumption of dwelling j .The estimation method is Three-way fixed effects Difference-in- Differences with staggered doption.

It should be clarified that, in the case of those dwellings that presented disconnection or cut before the switching month, I imputed the average consumption in the months before the change in which the residences had a positive consumption for the estimation exercises. These results to leave unaltered these observations and perform the exercises with zero consumption in the months before the switch.

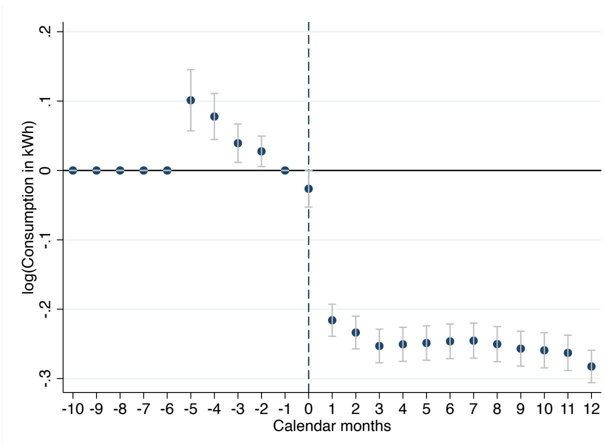
Besides, Figure 5 displays the point estimates of the non-parametric difference-in-differences (DiD) with staggered adoption specification over the same time window described above and, Table A.2 contains these estimates. However, I subdivided the sample by the regulation period. In other words, I create different sets of treated dwellings depending on the month in which they decided to switch and the regulation of EPM that was in force at that time. As can be seen in Figure 3, for those periods in which the number of switched dwellings was higher, between July 2010 and November 2011 and, after November 2014, it seems not to be an anticipatory behavior by users. As in the full sample case, the effect takes place the month following the switch, and is persistent over time. Moreover, analyzing the behavior of the coefficients after the switch in each of the regulatory periods, it seems that the total effect is being guided mainly by the first two regulation periods and, to a lesser degree, by the last regulation period.

In the case of the third, fourth and, to some extent, the fifth regulatory period (see Figures 6c , 6d and 6e) I observe a strong reduction in the magnitude of the coefficients, which could be partially explained by improvements in targeting on vurnerable population and users with debt, due to an imbalance in the optimal composition of the market. In 2011 EPM established that the financial viability of the program was associated with the consumption of households that were linked to the prepaid scheme and that, before the switch, presented significant delays in their payments. Therefore, after December 2011, the entry of users with minimal propensity to delay their payments was limited and, in April 2013, EPM established that users who wanted to request a transfer to the prepaid scheme should have a SISBEN score less or equal to 33.

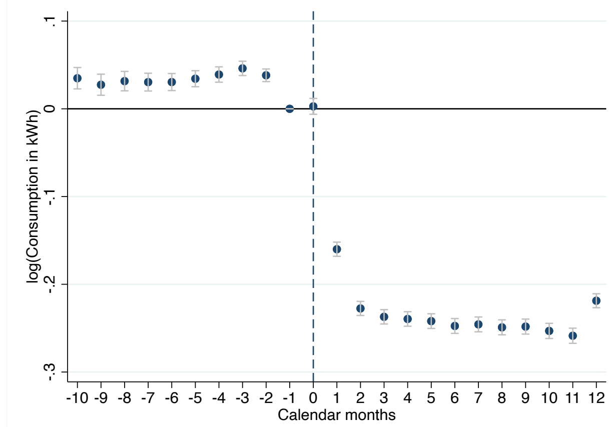
Given these regulatory changes in the program, I can expect that the population that was linked from this date obtained a significant reconnection benefit, but, given their conditions of high vulnerability, they were not able to significantly reduce their consumption. I suspect that the consumption of these users prior to the switch was very close to their minimum level required to subsist, but they could not afford the monthly payment of the service. By linking to the program, they were reconnected to the system and could consume according to their payment possibilities without affecting their budget.

Some descriptive evidence can support this hypothesis, particularly in the case of Medellín and its metropolitan area. For the regulatory periods three and four, the number of prepaid users who recharged, on average, more than once a month, is significantly higher than in the fifth regulatory period: 995 users recharge on average twice a month, 326 three times a month and 147 four times a month in the fourth regulatory period. In the case of the fifth regulatory period, 456 users recharge an average twice a month, 58 three times a month and 21 four times a month. Moreover, as can

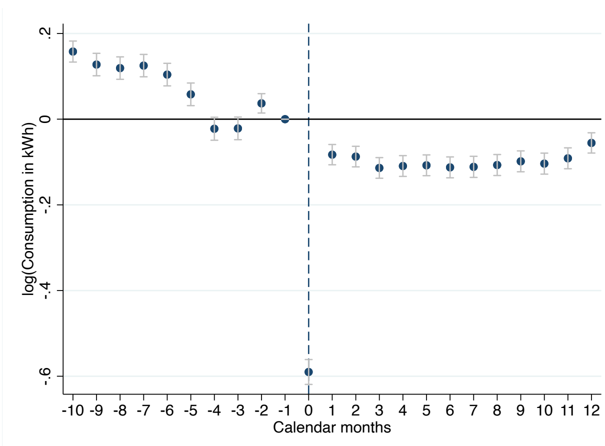
Figure 6: Effect of switching to the prepaid scheme on user's electricity consumption by regulation period.



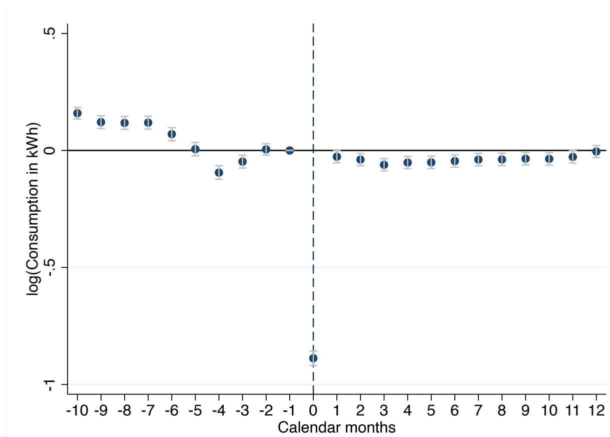
(a) First regulation period (Before July 2010).



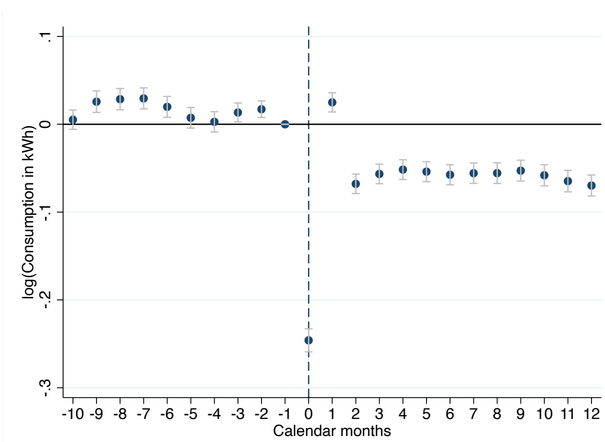
(b) Second regulation period (Between July 2010 and November 2011).



(c) Third regulation period (Between December 2011 and May 2013).



(d) Fourth regulation period (Between June 2013 and November 2014).

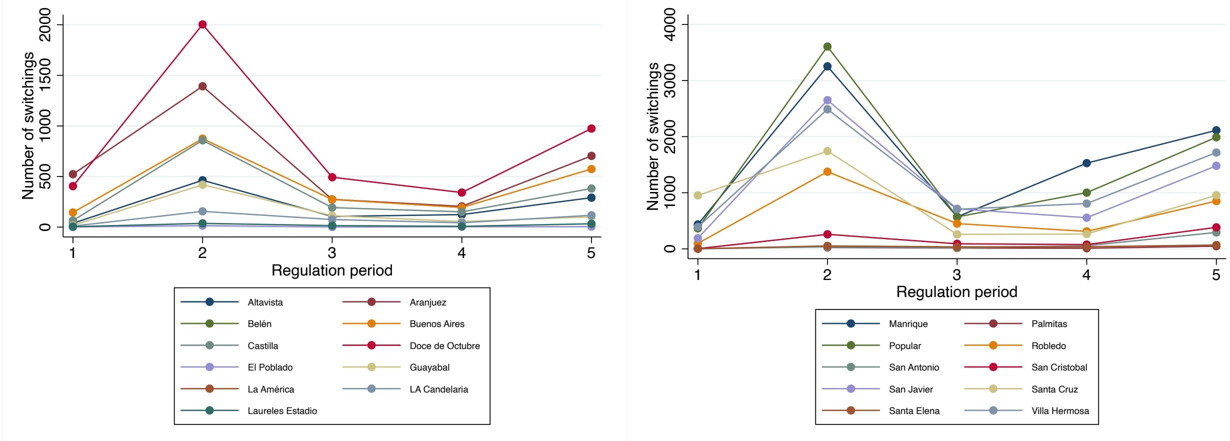


(e) Fifth regulation period (After November 2014).

Each regulation period includes those dwellings that decided to switch to the prepaid scheme during the term of the different decrees described in Section 2 and in the Figure 2.

be seen in the Figures 7a and 7b, the number of users who switched to the program since the third regulatory period and who are part of the most vulnerable communes in Medellín, like Manrique, Popular or Villa Hermosa, grew.

Figure 7: Number of swithings by commune and regultory period



(a) (b)

I interpret the magnitude of the findings by estimating equation 2, and I report the results of the parametric specification in Table 1. I find that switching to the prepaid scheme has a strongly and significant impact on electricity consumption. Column (2) shows a reduction in electricity consumption of 15.04% which, compared to the average user consumption in the sample before the change, represents a reduction of 20.88 kWh/month. This result is in line with those presented by Qiu et al. (2016); Nugrohoa et al. (2017); Jack and Smith (2015); OSullivan et al. (2013); Tewaria and Shah (2003); Ayres et al. (2012), among others. For example, Qiu et al. (2016) find that the prepaid program is associated with a 12% reduction in electricity usage and that customers with a lower level of wealth switch to the prepaid scheme.

Furthermore, columns (5) and (8) show that the effect is similar for both subgroups. However, it is stronger for those users who did not present some suspension or cut before the switching to the prepaid scheme. This last result presents some evidence to reject a possible hypothesis of "automatic effects" given the disconnection or cut of some users before the switch.

6 Mechanisms

I argue that the main channel behind the effect of the switch on the electricity consumption behavior is the tracking and budgeting electricity expenditure channel based on the real-time information that the user receives in the In-Home Display, and on the fact that in the prepaid scheme the

Table 1: The impact of prepaid schemes in electricity consumption

	Dependent variable: log of electric consumption in kWh								
	Full sample			Group with disconnection or cut			Group without disconnection or cut		
Variable	1	2	3	4	5	6	7	8	9
PostPrepaid	0.0816***	**-0.163*****	-0.163***	0.175***	**-0.125*****	-0.125***	0.0365***	**-0.182*****	-0.182***
	(0.00674)	(0.00194)	(0.00194)	(0.0119)	(0.00389)	(0.00389)	(0.00787)	(0.00213)	(0.00213)
Strata	0.159***			0.198***			0.161***		
	(0.00384))			(0.00657)			(0.00448)		
PostPrepaid×Strata	-0.0929***			-0.142***			-0.0919***		
	(0.00396)			(0.00693)			(0.00462)		
Observations	10,000,153	10,000,163	10,000,153	2,772,094	2,772,116	2,772,094	7,143,294	7,143,294	7,143,294
Clusters	138,171	138,173	138,171	45,035	45,037	45,035	91,114	91,114	91,114
R-squared	0.037	0.444	0.444	0.040	0.406	0.407	0.036	0.445	0.445
Adj R-squared	0.0371	0.4358	0.4359	0.0399	0.3963	0.3964	0.0354	0.4378	0.4379
Dwelling FE		✓	✓		✓	✓		✓	✓
Month FE	✓	✓	✓	✓	✓	✓	✓	✓	✓
Municipality/Month FE	✓		✓	✓		✓	✓		✓

Notes: Clustered standard errors in parenthesis. Significance level: *** 1% ** 5% * 10%. Estimation method: Difference-In-Differences.

provision of the electric service adapts to the dynamics of the household income. This approach is consistent with two of the four possible channels, present in the literature, via which a prepaid plan leads to electricity consumption reduction: nudging, price effects, information provision, and costs of discontinuation (Qiu et al., 2016).

Due to the prepaid scheme, users can understand their energy consumption better than when it is provided by standard billing. Conventional electricity schemes are postpaid, involving monthly billing and collections. This system implies that users receive information about quantities consumed and fees charged one month after the consumption. This scheme can lead to a certain kind of "inattention" to energy costs (Allcott and Greenstone, 2012). This "inattention" could lead users to not recognize opportunities to save money by choosing more efficient consumption patterns and avoiding overconsumption. I hypothesize that, due to the information provision, consumers reduce their overconsumption by tracking their energy use. This hypothesis is consistent with the results presented in the previous Section and with those presented in Figure A.6a.

In Figure A.6a, I represent the average consumption outside the subsidized range before and after the switch for dwellings of strata 1, 2, and 3. The computation of these averages takes into account only those dwellings that had non-zero consumption outside the subsidized range before the siwtch. I interpret this as a measure of overconsumption. If the prepaid plan leads to electricity consumption reduction through the information provided, I would expect that users of strata 1, 2, and 3 would be more aware of their consumption during the month and avoid exceeding the subsidized range of consumption. In contrast, Figure A.6b shows the average consumption before and after the switch for dwellings of strata 1, 2 and 3, that did not exhibited overconsumption before the switch. As can be seen, these dwellings seem to be increasing their electricity consumption, without exceeding the limits of the subsidized range. I suspect that, due to the information provision, these consumers are able to expand their consumption to more optimal levels, without exceeding subsidy limits.

I then estimate specifications 1 and 2, taking as the independent variable both, the consumption and the consumption outside the subsidized range. Results are presented in Figure 8 and table 2.

Columns 1 and 5 take into account all dwellings of strata 1, 2, and 3. Colum 1 shows that switching to the prepaid scheme has a strongly significant impact on overconsumption, if it was exhibited before the switch. Furthermore, columns 2-4 show that the effect is greater for stratum 3 users and follows a descending order. This finding can be explained both by the average levels of dwellings' consumption (Figure A.2) and the access to home appliances by users of strata 2 and 3. Since households of strata 2 and 3 have a higher level of income than those of stratum 1, they will be able to access more easily to appliances

In contrast, Column 5 shows that switching to the prepaid scheme generate an increase in electricity cosumption, if the user did not exhibited overconsumption before the switch. This effect is smaller than the reduction effect and occurs in a smaller proportion of the population linked to the program, which could explain the fact that when I analyze the complete sample (Figure 5), the reduction effect exceed the increase effect.

Table 2: The impact of prepaid schemes on overconsumption for low income users

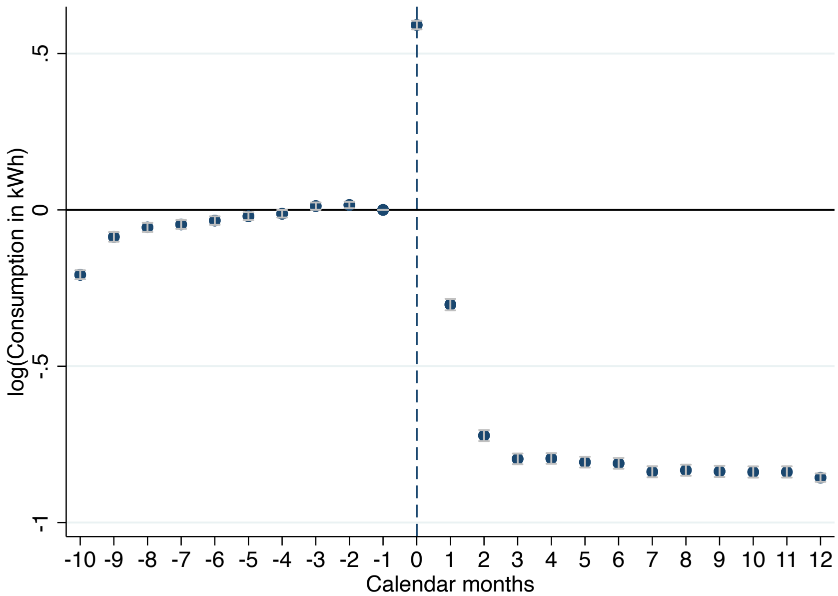
	Dependent variable: log consumption in kWh outside the subsidized range				**Dependent variable: log consumption in kWh**			
	Exhibited overconsumption				Did no exhibit overconsumption			
		Stratum 1	Stratum 2	Stratum 3		Stratum 1	Stratum 2	Stratum 3
Variable	1	2	3	4	5	6	7	8
PostPrepaid	-0.629***	-0.476***	-0.751***	-0.710***	0.215***	0.245***	0.177***	0.117***
	(0.00534)	(0.00957)	(0.00661)	(0.0124)	(0.00446)	(0.00585)	(0.00726)	(0.0196)
Observations	3,155,094	1,282,797	1,483,119	388,942	1,906,150	1,052,710	731,491	121,850
Clusters	97,564	45,367	42,356	9,820	29,221	17,498	10,095	1,625
R-squared	0.399	0.360	0.401	0.454	0.408	0.424	0.380	0.393
Adj R-squared	0.519	0.406	0.479	0.691	0.3985	0.4134	0.3701	0.3823

Notes: Clustered standard errors in parenthesis. Significance level: *** 1% ** 5% * 10%. Estimation method: Three-way fixed effects Difference-In-Differences with staggered adoption. Dwelling, time and municipality-time fixed effects included.

With regard to the pricing mechanism, due to Colombian regulation, the fee charged to users is the same in both schemes, postpaid and prepaid. However, in the postpaid scheme, consumers enjoy the time value of money (Qiu et al., 2016) for the amount recharged while they are consuming electricity and the electric service provision adapts to the dynamics of the household income, easing its budget constraint. Furthermore, the prepaid scheme and the support given by EPM staff about the use of the new scheme, the new meter and about efficient energy consumption strategies could nudge households to alter their energy consumption. The way in which this scheme operates and the additional information it provides, might increase autonomy and agency (Kasperbauer, 2017), while it make easier for users to act according to their preferences and possibilities. The empirical review of these mechanisms is beyond the scope of this article and only corresponds to anecdotal evidence provided by EPM.

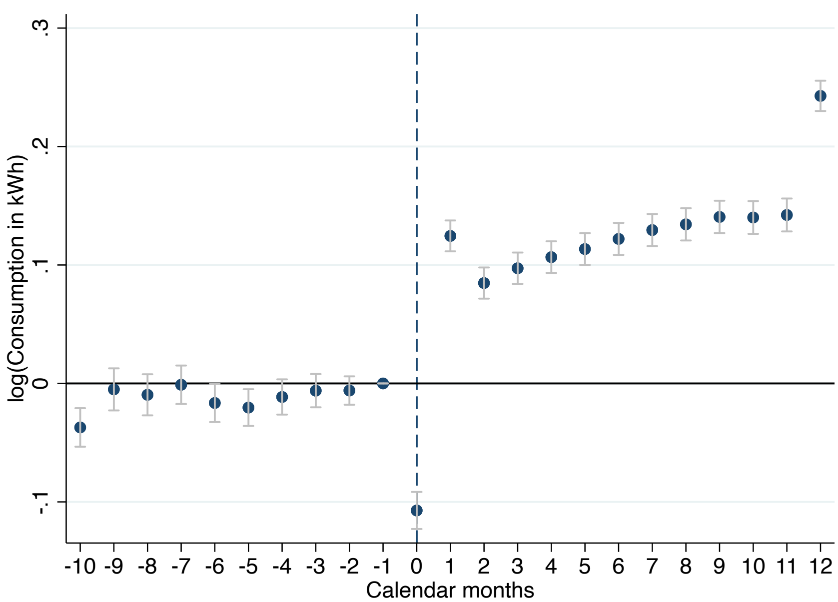
Figure 8: Effect of switching to the prepaid scheme on user's electricity consumption II.

(a) Dwellings that exhibited overconsumption before the switch.



Independent variable: log consumption outside the subsidized range

(b) Dwellings that did not exhibited overconsumption before the switch.



Independent variable: log consumption

This Figure shows the coefficients from equation 1. The estimation method is Three-way fixed effects Difference-in-Differences with staggered doption.

7 Conclusions

In this paper, I analyze the impact that switching to a prepaid electricity program has on the behavior of users' energy consumption, mainly on those that are more vulnerable from a socio-economic point of view. The paper is guided by one central question: how is affected the energy consumption of a dwelling, which may or may not have the electric power service discounted or cut off, when it is passed to a prepaid scheme, where he can self-manage his consumption and consume according to his payment possibilities? I find that switching to the prepaid scheme has a strongly significant impact on electricity consumption. This is, a reduction of 15.04% compared to the consumption under a postpaid scheme.

Nevertheless, when I divide the sample among those households that presented overconsumption before the switch and those that did not, I find two conflicting results. Dwellings of strata 1, 2 and 3, that exhibited overconsumption before the switch, reduced their consumption outside the subsidized range in 46.69%, but dwellings of strata 1, 2 and 3, that did not exhibit overconsumption before the switch, increased their electricity consumption in 23.9%. Analyzing the dynamics, I observe that these effects are persistent over time, even 12 months after the switch.

Besides, this kind of program introduces new flexibility in how and when low-income users purchase energy. As pointed out by (Jack and Smith, 2015), allowing households to smooth expenditures according to their income stream, much of which comes from informal labor relations. As shown in Section 6, this scheme allows users to generate consumption reductions, while their access to public electricity services is guaranteed, minimizing disconnection risks and the associated costs.

This kind of energy efficiency is relevant both for the Colombian context and its energy sufficiency in the medium and long term, and for the global context, since the European Commission has listed improved energy efficiency among its top objectives for 2020, and most countries that have ratified the recent Paris Agreement plan to improve energy efficiency in order to meet their goals (The European Commission, 2010; International Energy Agency, 2014). Furthermore, many international institutions pointed out that energy efficiency is the best tool to keep energy demand under control, as can be done with a prepaid scheme like the one analyzed in this article, while it facilitate the transition towards a low-carbon future (Ramos et al., 2015).

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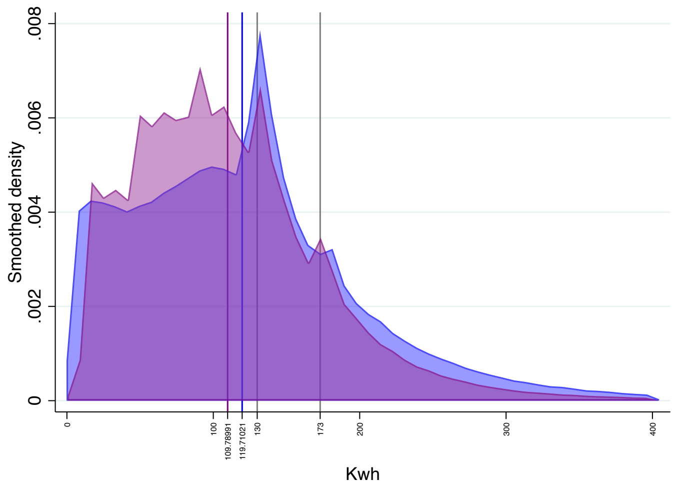
8 Appendix

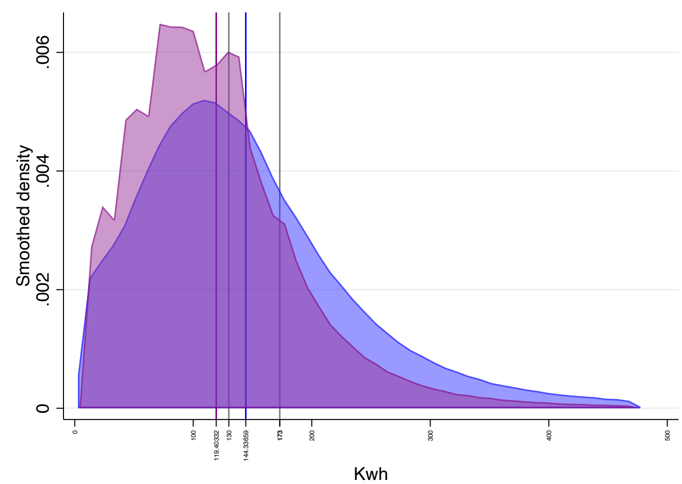
Figure A.1: Installation of a prepaid meter in May of 2009

Source: EPM.

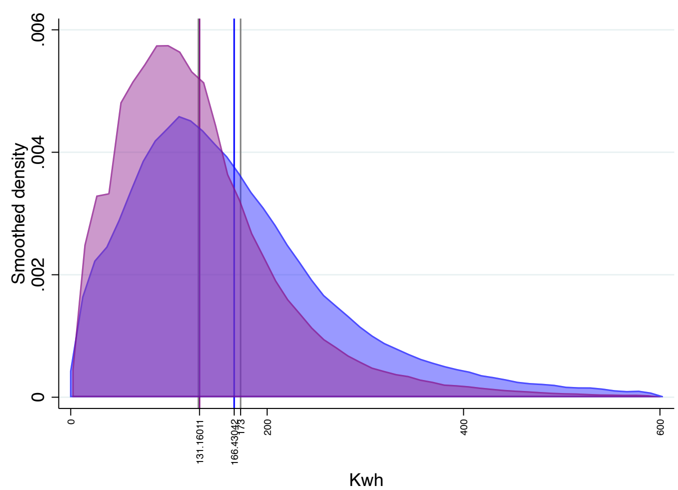
Figure A.2: Smoothed kernel density of consumption in both schemes by strata



(a) Stratum 1



(b) Stratum 2



(c) Stratum 3

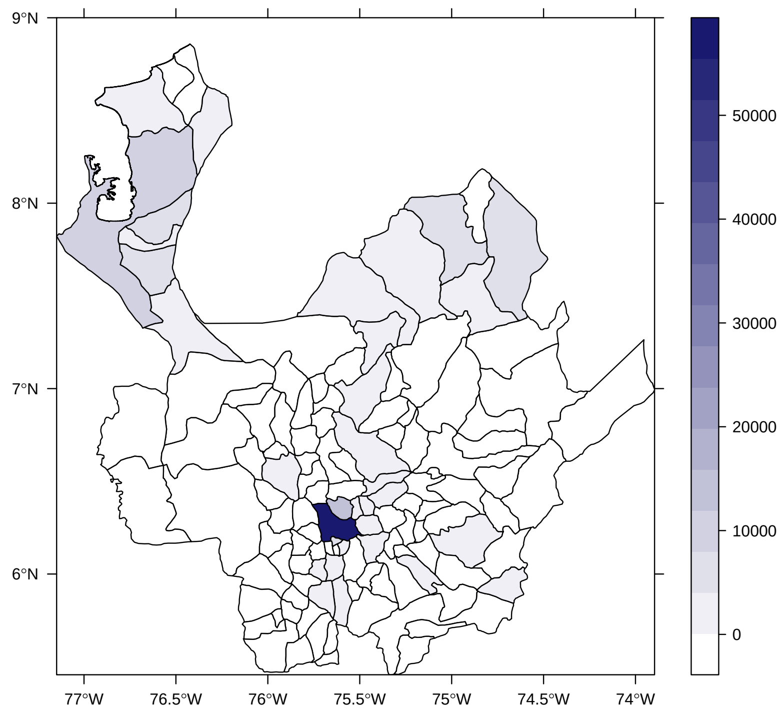
A trimming of 1% was done in both tails of the consumption distribution. The kernel desnties plotted in blue correspond to dwelling's consumption under the postpaid scheme and those plotted in purple correpond to dwelling's consumption under the prepaid scheme. Gray lines represent the limits of the subsidized range, subject to the height of the municipality.

Table A.1: Electricity consumption by stratum and billing scheme

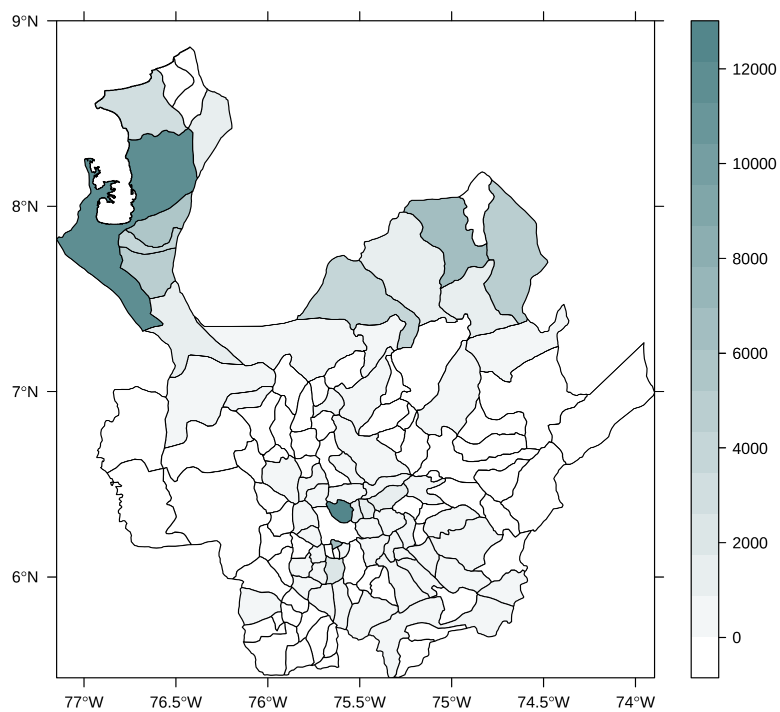
	Billing Scheme	
Strata	Postpaid	Prepaid
Stratum 1	119. 71	109.79
	(75.17)	(64.07)
Stratum 2	144.34	119.40
	(87.23)	(70.71)
Stratum 3	166.43	131.16
	(107.34)	(87.00)
Obs	3,865,657	6,486,136

Notes: A trimming of 1% is made in both tails of the consumption distribution.

Figure A.3: This Figure represents the number of switched dwellings between 2010-2017.



(a) All municipalities in Antioquia



(b) Municipalities in Antioquia without Medellín

Table A.2: The impact of prepaid schemes in electricity consumption

	Dependent variable: log of electric consumption in kWh					
	Full sample		Group with disconnection or cut		Group without disconnection or cut	
Variable	1	2	3	4	5	6
10 months before	-0.0155***	-0.0155***	-0.378***	-0.380***	-0.0222***	-0.0223***
	(0.00342)	(0.00342)	(0.116)	(0.116)	(0.00366)	(0.00366)
9 months before	0.0108***	0.0108***	-0.412***	-0.413***	0.0332***	0.0333***
	(0.00380)	(0.00380)	(0.116)	(0.116)	(0.00384)	(0.00384)
8 months before	0.0159***	0.0160***	-0.429***	-0.431***	0.0455***	0.0456***
	(0.00370)	(0.00370)	(0.116)	(0.116)	(0.00368)	(0.00368)
7 months before	0.0207***	0.0208***	-0.448***	-0.450***	0.0564***	0.0565***
	(0.00358)	(0.00358)	(0.116)	(0.116)	(0.00351)	(0.00351)
6 months before	0.0122***	0.0121***	-0.513***	-0.515***	0.0633***	0.0631***
	(0.00353)	(0.00353)	(0.116)	(0.116)	(0.00340)	(0.00340)
5 months before	0.00401	0.00386	-0.606***	-0.608***	0.0717***	0.0715***
	(0.00344)	(0.00344)	(0.116)	(0.116)	(0.00322)	(0.00322)
4 months before	-0.00605*	-0.00613*	-0.753***	-0.755***	0.0776***	0.0775***
	(0.00334)	(0.00334)	(0.116)	(0.116)	(0.00305)	(0.00305)
3 months before	0.0133***	0.0131***	-0.853***	-0.855***	0.0885***	0.0881***
	(0.00312)	(0.00312)	(0.116)	(0.116)	(0.00279)	(0.00279)
2 months before	0.0254***	0.0252***	-1.085***	-1.086***	0.0870***	0.0868***
	(0.00270)	(0.00270)	(0.116)	(0.116)	(0.00235)	(0.00235)
Switching month	-0.261***	-0.261***	-1.569***	-1.571***	0.199***	0.199***
	(0.00377)	(0.00377)	(0.116)	(0.116)	(0.00290)	(0.00290)
1 month after	-0.0908***	-0.0907***	-0.580***	-0.581***	-0.0431***	-0.0433***
	(0.00304)	(0.00304)	(0.116)	(0.116)	(0.00307)	(0.00308)
2 months after	-0.155***	-0.155***	-0.550***	-0.551***	-0.147***	-0.147***
	(0.00305)	(0.00305)	(0.116)	(0.115)	(0.00306)	(0.00306)
3 months after	-0.162***	-0.162***	-0.540***	-0.542***	-0.161***	-0.161***
	(0.00307)	(0.00307)	(0.116)	(0.116)	(0.00310)	(0.00310)
4 months after	-0.160***	-0.160***	-0.528***	-0.529***	-0.163***	-0.163***
	(0.00310)	(0.00310)	(0.116)	(0.116)	(0.00315)	(0.00315)
5 months after	-0.163***	-0.163***	-0.524***	-0.526***	-0.168***	-0.168***
	(0.00313)	(0.00313)	(0.116)	(0.116)	(0.00319)	(0.00319)
6 months after	-0.167***	-0.167***	-0.524***	-0.525***	-0.174***	-0.174***
	(0.00315)	(0.00315)	(0.116)	(0.116)	(0.00323)	(0.00323)
7 months after	-0.165***	-0.165***	-0.515***	-0.516***	-0.175***	-0.175***
	(0.00317)	(0.00317)	(0.116)	(0.116)	(0.00325)	(0.00326)
8 months after	-0.168***	-0.168***	-0.513***	-0.515***	-0.179***	-0.179***
	(0.00319)	(0.00319)	(0.116)	(0.116)	(0.00328)	(0.00328)
9 months after	-0.166***	-0.166***	-0.507***	-0.508***	-0.179***	-0.180***
	(0.00320)	(0.00320)	(0.116)	(0.116)	(0.00330)	(0.00330)
10 months after	-0.173***	-0.173***	-0.511***	-0.512***	-0.187***	-0.187***
	(0.00324)	(0.00324)	(0.116)	(0.116)	(0.00335)	(0.00335)
11 months after	-0.176***	-0.176***	-0.512***	-0.513***	-0.191***	-0.191***
	(0.00325)	(0.00325)	(0.116)	(0.116)	(0.00336)	(0.00336)
12 months after	-0.167***	-0.167***	-0.473***	-0.475***	-0.187***	-0.187***
	(0.00307)	(0.00307)	(0.116)	(0.116)	(0.00313)	(0.00313)
Observations	9,915,410	9,915,400	2,772,116	2,772,094	7,143,294	7,143,294
Clusters	136,151	136,149	45,037	45,035	91,114	91,114
R-squared	0.441	0.441	0.430	0.430	0.449	0.450
Adj R-squared	0.4331	0.4332	0.4202	0.4203	0.4423	0.4424
Dwelling FE	✓	✓	✓	✓	✓	✓
Month FE	✓	✓	✓	✓	✓	✓
Municipality-Month FE		✓		✓		✓

Notes: Clustered standard errors in parenthesis. Significance level: *** 1% ** 5% * 10%.
Estimation method: Difference-In-Differences with staggered adoption.

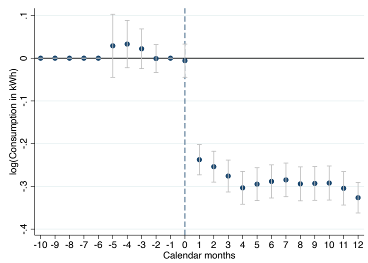
Table A.3: The impact of prepaid schemes in electricity consumption by regulation period

	Dependent variable: log of electric consumption in kWh				
	First Regulation Period	Second Regulation Period	Third Regulation Period	Fourth Regulation Period	Fifth Regulation Period
Variable	1	2	3	4	5
10 months before		0.0349***	0.158***	0.159***	0.00519
		(0.00622)	(0.0125)	(0.0128)	(0.00559)
9 months before		0.0274***	0.127***	0.121***	0.0257***
		(0.00614)	(0.0134)	(0.0141)	(0.00622)
8 months before		0.0316***	0.119***	0.118***	0.0286***
		(0.00564)	(0.0134)	(0.0141)	(0.00616)
7 months before		0.0304***	0.125***	0.119***	0.0295***
		(0.00517)	(0.0133)	(0.0141)	(0.00610)
6 months before		0.0305***	0.104***	0.0698***	0.0198***
		(0.00494)	(0.0134)	(0.0143)	(0.00606)
5 months before	0.101***	0.0343***	0.0580***	0.00557	0.00736
	(0.0225)	(0.00467)	(0.0135)	(0.0146)	(0.00599)
4 months before	0.0778***	0.0391***	-0.0224	-0.0945***	0.00280
	(0.0169)	(0.00445)	(0.0137)	(0.0148)	(0.00586)
3 months before	0.0393***	0.0461***	-0.0215	-0.0476***	0.0134**
	(0.0141)	(0.00416)	(0.0135)	(0.0141)	(0.00553)
2 months before	0.0276**	0.0382***	0.0370***	0.00445	0.0171***
	(0.0112)	(0.00367)	(0.0115)	(0.0125)	(0.00483)
Switching month	-0.0264*	0.00281	-0.590***	-0.888***	-0.246***
	(0.0135)	(0.00461)	(0.0148)	(0.0157)	(0.00667)
1 month after	-0.216***	-0.160***	-0.0828***	-0.0267**	0.0249***
	(0.0118)	(0.00413)	(0.0121)	(0.0132)	(0.00559)
2 months after	-0.234***	-0.228***	-0.0874***	-0.0390***	-0.0678***
	(0.0120)	(0.00411)	(0.0122)	(0.0134)	(0.00566)
3 months after	-0.253***	-0.237***	-0.114***	-0.0613***	-0.0566***
	(0.0123)	(0.00417)	(0.0123)	(0.0134)	(0.00569)
4 months after	-0.251***	-0.240***	-0.109***	-0.0515***	-0.0516***
	(0.0125)	(0.00422)	(0.0124)	(0.0135)	(0.00574)
5 months after	-0.249***	-0.242***	-0.108***	-0.0508***	-0.0539***
	(0.0127)	(0.00426)	(0.0124)	(0.0135)	(0.00581)
6 months after	-0.246***	-0.248***	-0.112***	-0.0452***	-0.0575***
	(0.0127)	(0.00431)	(0.0124)	(0.0135)	(0.00586)
7 months after	-0.245***	-0.246***	-0.111***	-0.0389***	-0.0557***
	(0.0129)	(0.00432)	(0.0126)	(0.0136)	(0.00592)
8 months after	-0.250***	-0.249***	-0.107***	-0.0385***	-0.0556***
	(0.0129)	(0.00435)	(0.0125)	(0.0136)	(0.00599)
9 months after	-0.257***	-0.248***	-0.0984***	-0.0351***	-0.0528***
	(0.0129)	(0.00437)	(0.0124)	(0.0136)	(0.00606)
10 months after	-0.259***	-0.253***	-0.104***	-0.0359***	-0.0580***
	(0.0129)	(0.00441)	(0.0125)	(0.0137)	(0.00615)
11 months after	-0.263***	-0.259***	-0.0913***	-0.0276**	-0.0648***
	(0.0130)	(0.00441)	(0.0124)	(0.0137)	(0.00623)
12 months after	-0.283***	-0.219***	-0.0554***	-0.00443	-0.0698***
	(0.0119)	(0.00406)	(0.0121)	(0.0131)	(0.00609)
Observations	476,297	4,350,676	954,004	1,008,443	3,125,958
Clusters	5,310	52,516	12,783	14,548	50,992
R-squared	0.438	0.447	0.418	0.408	0.456
Adj R-squared	0.4319	0.4398	0.4093	0.3991	0.4469

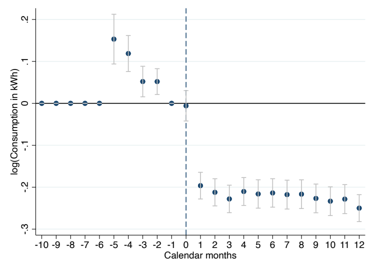
Notes: Clustered standard errors in parenthesis. Significance level: *** 1% ** 5% * 10%.Estimation method: Three-way fixed effects Difference-In-Differences with staggered adoption. Dwelling, time and municipality-time fixed effects included.

Figure A.4: Effect of switching to the prepaid scheme on user's electricity consumption by regulation period and strata

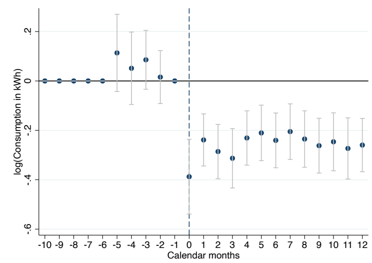
Firts regulation period



(a) Stratum 1: 2,228 dwellings



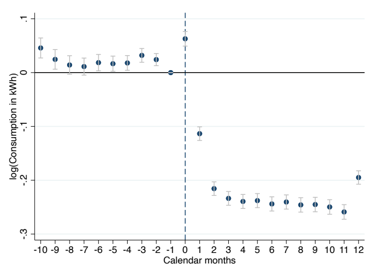
(b) Stratum 2: 2,793 dwellings.



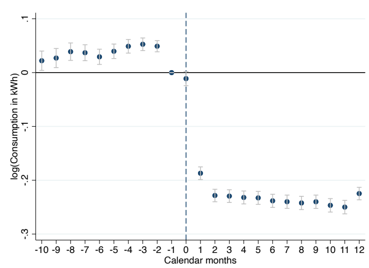
(c) Stratum 3: 288 dwellings.

(Before July 2010).

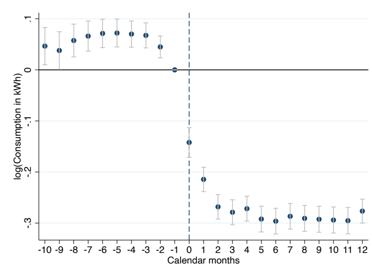
Second regulation period



(d) Stratum 1: 21,633 dwellings.



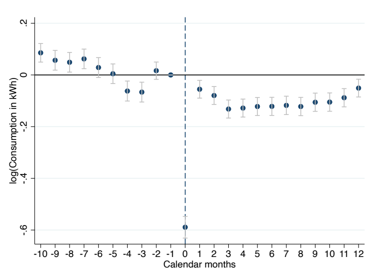
(e) Stratum 2: 24,498 dwellings.



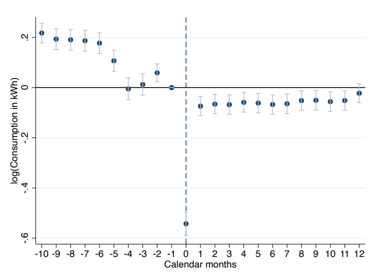
(f) Stratum 3: 6,150 dwellings.

(Between July 2010 and November 2011).

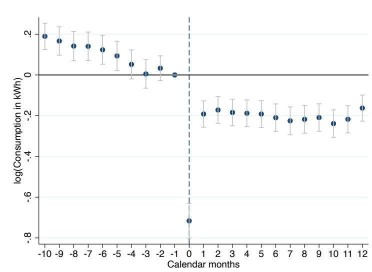
Third regulation period



(g) Stratum 1: 5,888 dwellings.



(h) Stratum 2: 5,179 dwellings.

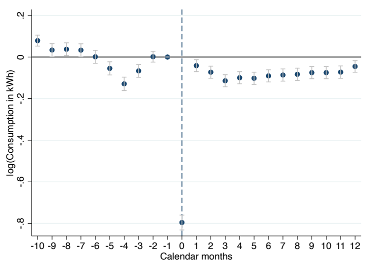


(i) Stratum 3: 1,623 dwellings.

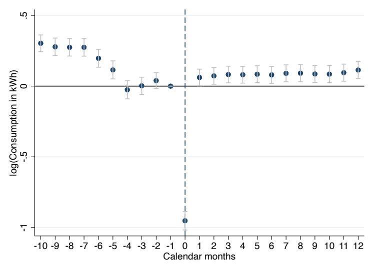
(Between December 2011 and May 2013).

Effect of switching to the prepaid scheme on user's electricity consumption by regulation period and strata

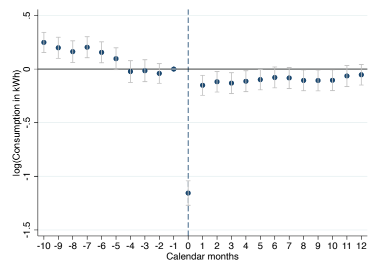
Fourth regulation period



(j) Stratum 1: 8,543 dwellings.



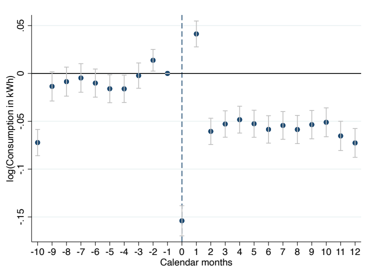
(k) Stratum 2: 4,686 dwellings.



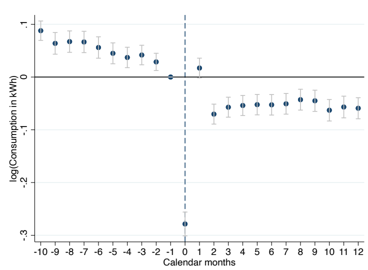
(l) Stratum 3: 1,244 dwellings.

(Between June 2013 and November 2014).

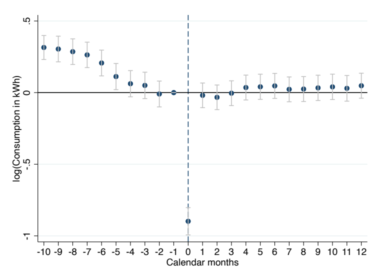
Fifth regulation period



(m) Stratum 1 30,911 dwellings.



(n) Stratum 2: 17,231 dwellings.

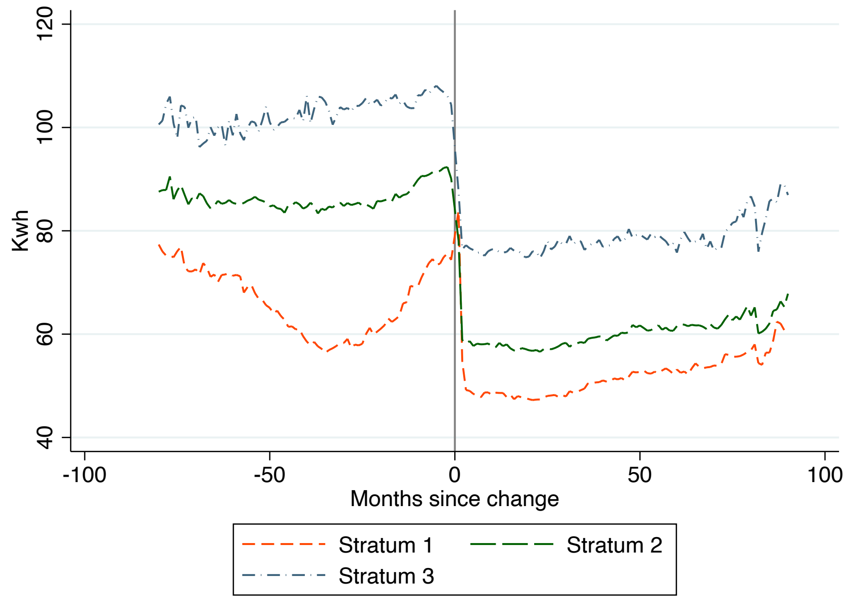


(o) Stratum 3: 2,469 dwellings.

(After November 2014).

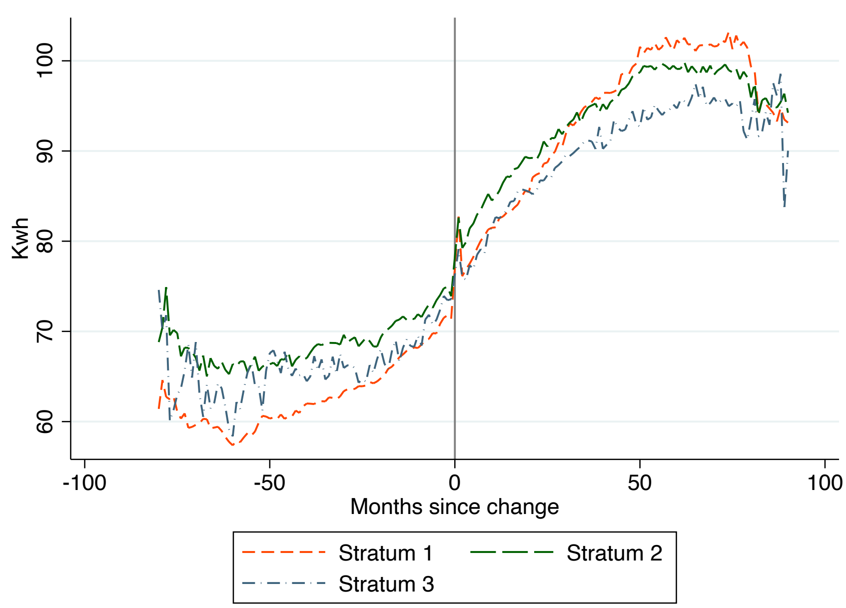
Figure A.6: Raw data

(a) Average consumption outside the subsidized range before and after the switch



This Figure represents the average consumption outside the subsidized range before and after the switch for dwellings of strata 1, 2 and 3, that exhibited overconsumption before the switch.

(b) Average consumption inside the subsidized range before and after the switch



This Figure represents the average consumption before and after the switch for dwellings of strata 1, 2 and 3, that did not exhibited overconsumption before the switch.