

Short- and long-term price elasticity of residential energy consumption: Evidence from a natural experiment with social tariff*

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Abstract

Energy price elasticities for residential consumers is probably the most important variable to define policies regarding concerns about sustainability, efficiency and equitability. However, estimating consumer response to price changes is complex due to simultaneous demand shocks, regulatory constraints and complex consumer response for this market. This paper estimates the short- and long-term price elasticity of residential energy consumption through a natural experiment from the implementation of a Social Electricity Tariff in Tucumán, Argentina. The policy, aimed at assisting vulnerable households, provided a subsidy to the fixed charge of the electricity tariff but initially reached only a small set of highly vulnerable users. A difference-in-differences approach is employed, with low-income households initially not covered by the social tariff serving as the control group. Our findings indicate that price elasticity is inelastic, with a more pronounced effect among lower-consumption users. This study provides, to our knowledge, the first quasi experimental estimate of short- and long-term price elasticity for Latin America, offering valuable insights for the design of energy policies.

Keywords: Price elasticity, Residential energy consumption, Social Tariff, Energy subsidy, Difference-in-Differences, Heterogeneous effects, Short- and Long-term.

JEL: C23, D12, H31, Q41, Q48.

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1 Introduction

Among the various goods and services in modern society, few are as essential as electricity. It plays a crucial role in supporting both productive activities and the daily routines of households (International Energy Agency, 2021; Inter-american Development Bank, 2020). Over recent decades, the rising demand for energy has prompted significant debate surrounding the sustainability and efficiency of its utilization, encompassing a range of issues from environmental considerations to household welfare and productive efficiency (Zou et al., 2020; Phoumin and Kimura, 2014). To address these challenges, it is vital to understand how consumers respond to changes in electricity prices, making the estimation of price elasticity essential.

Despite the importance of this topic and the existence of economic literature on energy demand dating back to the last century, with its inception marked by Houthakker (1951), estimating consumer responses to price shocks remains a challenge (Nataraj and Hanemann, 2011). It is often the case that price changes coincide with demand shocks or impact all users simultaneously, while experimental evaluations are exceedingly complex due to regulatory constraints. Moreover, two specific aspects of consumer response to price shocks contribute to the complexity of this issue. On one hand, energy demand is derived from the use of durable goods. Both temporary and permanent price changes can produce varying responses in the short- and medium-term, often related to changes in usage or investment in these durable goods (Berndt and Samaniego, 1984; Poblete-Cazenave and Pachauri, 2021). On the other hand, recent studies suggest that electricity consumers may not respond as predicted by standard economic theory. The marginal rate of nonlinear pricing structures commonly applied in energy markets is not fully understood by the majority of individuals (Ito, 2014; Wichman, 2014).

Our work contributes to this literature by estimating the short- and long-term price elasticity of residential energy consumption through a quasi-experimental identification strategy. To achieve this, we employ a natural experiment resulting from the implementation of a Social Electricity Tariff in the province of Tucumán, Argentina, in January 2021. This policy provided a subsidy on the fixed charge of the electricity bill with the intention of assisting vulnerable households in managing their energy consumption costs. However, its implementation was not immediate. During the first year, the social tariff reached only a limited portion of its target population: users in highly vulnerable socio-economic situation.

A difference-in-differences design was employed to estimate the effect of the subsidy on residential user consumption, using vulnerable households that did not access the social tariff in the first year of its implementation as the control group.

Our results indicate that the policy resulted in an average increase in residential consumption of 3.05% in the short term and 1.92% in the long term. The effect on consumption is reflected in elasticity values ranging from -0.12 to -0.50 throughout the analysed months. Additionally, we found evidence of heterogeneous effects across different consumption levels. In

particular, an examination of the lowest consumption category among vulnerable households revealed no significant effect from the social tariff. This may be attributed to the constraints these households face in adjusting their consumption, as they are already close to the threshold of their energy capacities. Elasticity is more pronounced among the middle consumption groups, with values between -0.18 and -0.31 in the short term and -0.17 and -0.24 in the long term.

As previously mentioned, the existing literature on the price elasticity of energy consumption is both extensive and complex. This diversity is reflected in the wide variety of results, data, and methods used in the estimation process. In a comprehensive study, Labandeira et al. (2017) conducted a meta-analysis of 428 empirical studies on the price elasticity of energy demand from 1990 to 2016. The analysis distinguishes the effects of estimations based on characteristics such as the reference country, the type of consumer, the duration of the analysed period, the data employed, and the models used. The values reported fall within an elasticity range of -0.13 to -0.37 for the short- and long-term, respectively.

The authors emphasise that studies using microdata to estimate the price elasticity of energy demand are scarce, which limits the capacity to capture the heterogeneity in household behaviour—a crucial element for attaining precise estimates. Furthermore, they point out the lack of empirical evidence regarding elasticities in developing countries, particularly in Latin America, where few studies have addressed specific cases.¹ They also observe that energy demand elasticities vary between developed and developing countries. However, these differences only manifest in the long term, suggesting that income convergence could affect energy demand, with implications for environmental concerns and dependence on foreign sources. In this context, our study makes a significant contribution by providing specific evidence for Argentina and Latin America based on residential household data, allowing for a detailed analysis of the heterogeneity in consumption. This provides a relevant signal for policymakers regarding about future energy challenges, underscoring the importance of designing sustainable policies that adapt to changes in energy demand.

Among the closest works to ours, Zou et al. (2020) investigates the impact of the Incremental Block Pricing (IBP) policy on electricity conservation in the Chinese provinces of Guangdong, Sichuan, and Shanghai between 2011 and 2012. Using a difference-in-differences (DiD) approach, they find that the implementation of IBP significantly reduces consumption across various specifications and throughout all provinces. However, they highlight that the effects vary according to income levels and provinces, with a greater influence observed in middle and high-income sectors.

Finally, Ito (2014) employs a spatial regression discontinuity design to demonstrate that

1. Of the total studies considered in the article, none estimate elasticity for Argentina, and only six studies address cases from Chile, Uruguay, or Brazil.

high information costs and the complexity of tariff structures lead consumers to use the average price as a practical approximation of the marginal price.² Their results indicate that both the price elasticity of marginal (MP) and the expected price elasticity of marginal (EMP) are not significantly different from zero, while the average price elasticity (AP) is significant, with a value between -0.054 and -0.086.³ The Social Tariff consisted of a subsidy applied to the fixed charge of the electricity tariff, while the variable charge remained the same for both beneficiaries and non-beneficiaries. The reaction of consumers under this scheme suggests that they are sensitive to average prices, thereby supporting their findings. This enriches the literature on complex tariff schemes and perceived prices, providing guidance for future tariff modifications and other types of pricing policies.

To the best of our knowledge, this study provides the first estimates of short- and long-term price elasticity for Latin America using a quasi-experimental strategy, thereby making a fundamental contribution to the development of energy policies in the region. Our results contribute to the existing literature, concluding that the demand for electricity is inelastic and that the subsidy had significant effects on the consumption of vulnerable households. Secondly, this work broadens the ongoing discussion on consumer heterogeneity by demonstrating that there is a greater reaction from medium-consumption households, while the effects are of lesser magnitude at the extremes. These findings are particularly relevant when designing policies aimed at improving the wellbeing of vulnerable households.⁴ Finally, it provides valuable insights for microeconomic theory regarding consumer behaviour.

The remainder of the paper is organised as follows. Section 2 provides an overview of the institutional background and the tariff structures. Section 3 presents our identification strategy, the structure of the data, and the model employed. Section 4 discusses the results obtained from our estimation, while Section 6 summarises the main findings, implications, and limitations of the study.

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2. This aspect generates an interesting discussion in this field. Some authors argue that consumers respond to the marginal price only when faced with large magnitude changes (Zhang et al., 2017; Nataraj and Hanemann, 2011).
 3. Table A.1 in the appendix summarizes some findings from the literature.
 4. In this regard, Schaffitzel et al. (2020) argue that there are more efficient alternatives in terms of both expenditure and welfare, such as strengthening assistance programs, implementing consumption voucher systems, or improving the provision of health services for the most vulnerable households.

2 Institutional background and tariff design

In the province of Tucumán, EDET S.A. is responsible for the annual supply of approximately 2,700 GWh of electricity to over 530,000 users, reaching 1.6 million inhabitants.⁵ Moreover, its activity is subject to regulation by the Ente Único de Control y Regulación de los Servicios Públicos Provinciales de Tucumán (ERSEPT), an autarkic entity of the Provincial State.

On 8 January 2021, significant changes were introduced to the electricity tariff scheme, emphasising the implementation of the **Social Electricity Tariff** (TSE, for its acronym in Spanish), which is a subsidy for electricity consumption reflected in the fixed charge of the bill. This policy was introduced with the objective of guaranteeing universal access to an essential service, with a particular focus on those most vulnerable within the province.⁶ In order to implement this, ERSEPT defined the criteria to determine which users would be eligible, with the objective of reaching all households facing socioeconomic vulnerability. In order to qualify, the service holders were required to meet at least one of the following conditions:

- Beneficiaries of Universal Child Allowance (AUH) and Pregnancy Allowance.
- Beneficiaries of non-contributory pensions with gross income up to twice the Living Minimum Wage.
- Users registered in the Social Monotax Scheme.
- Retirees, pensioners, and employees with gross income up to twice the Living Minimum Wage.
- Self-employed individuals (monotributistas) with annual income, on a monthly basis, up to twice the Living Minimum Wage.
- Unemployment insurance beneficiaries.
- Users reliant on electricity for medical reasons (electrodependents).
- Domestic Workers under the Special Social Security Scheme.

Moreover, households with outstanding debts with the distribution company or with multiple services registered under their name are ineligible for the subsidy, in accordance with the decision of ERSEPT.⁶

The initial identification of eligible households was the responsibility of the National Energy Secretariat. In order to achieve this, a combination of data was employed, provided by EDET and the National Fiscal and Social Information System (SINTyS). This allowed the necessary cross-checking of information to identify service holders who met the required socio-economic conditions. Once these households had been identified, the Secretariat provided the information to ERSEPT, who in turn provided it to EDET, which was responsible for applying the subsidy

5. <https://www.edetsa.com/info/pwa/institucional/quienes-somos>.

6. RES ERSEPT N°645/20 - RTI EDET SA 2020-2025.

to the relevant users in its billing system. Furthermore, the distribution company was tasked with excluding households that meet the exclusion criteria. Finally, ERSEPT periodically consults with the company on the list of beneficiaries to ensure the correct allocation of the subsidy.

In its initial phase, the social tariff reached 305,694 of the residential users who received a 45% discount on the fixed charge of their electricity bill, representing 54% of all households. Some households, despite meeting vulnerability requirements, were excluded from the benefit. This occurred in cases where the service holder did not meet the conditions, although other household members might have, and in cases where one of the exclusion criteria was met.

In addition to the subsidy implementation, there were other important tariff reforms:

1. The tariff schedule is divided into a fixed charge with four increasing price blocks and a uniform variable charge.
2. The fixed charge rises sharply and the variable charge falls for almost all but very high levels of electricity consumption.
3. The weight of the fixed component in the total bill increases significantly.
4. The fixed charge category is defined on the basis of the user's 12-month moving average consumption, (MA(12)).⁷
5. Consumption exceeding 750 kWh per month is subject to a surcharge, except for beneficiaries of the social tariff.

Table 1 and 2 shows the tariff chart before and after the implementation of these changes.

Table 1: Small residential demands tariff chart. In effect during the year 2020.

Category*	Unit	Fixed charge	Unit	Variable charge
Consumption $\leq$ 200 kWh/bim	\$/bim	92.64	\$/kWh	3.3468
Consumption between 200 and 300 kWh/bim	\$/bim	180.87	\$/kWh	3.5136
Consumption between 300 and 600 kWh/bim	\$/bim	222.04	\$/kWh	4.2498
Consumption between 600 and 900 kWh/bim	\$/bim	294.09	\$/kWh	4.4166
Consumption $\geq$ 900 kWh/bim	\$/bim	382.32	\$/kWh	4.7406

Source: Resolutions N°836/19 and 645/20 - ERSEPT.

Notes: *The category is defined based on consumption from the two months immediately prior to the meter reading.

7. Calculated excluding periods with zero kWh consumption.

Table 2: Small residential demands tariff chart. In effect as of January 2021.

Fixed charge*	Unit	Charge	TSE	TSE/Charge
C1: Consumption $\leq$ 150 kWh/month	\$/month	206.25	-92.81	45%
C2: Consumption between 150 and 250 kWh/month	\$/month	413.62	-186.13	45%
C3: Consumption between 250 and 550 kWh/month	\$/month	894.98	-402.74	45%
C4: Consumption $\geq$ 550 kWh/month	\$/month	1,761.48	-792.67	45%
Variable charge	Unit	Charge	TSE	TSE/Charge
Charge	\$/kWh	2.9343	-	-
Surcharge for consumption over 750 kWh/month**	\$/kWh	1.6432	-1.6432	100%

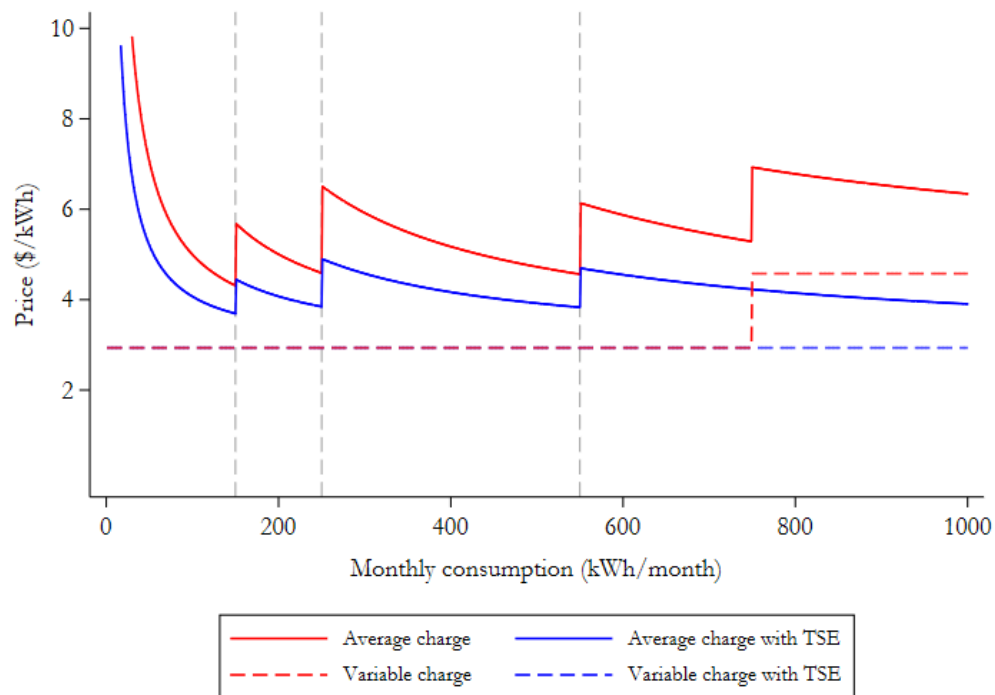
Source: Resolutions N°645/20 - ERSEPT.

Notes: *The category is defined based on the average consumption over the last 12 months, excluding periods with zero kWh consumption. **Social Electricity Tariff beneficiaries are exempt.

The new scheme, which introduced a fixed charge subsidy for a limited group of users, resulted in a significant price difference between TSE beneficiaries and non-beneficiaries. This is illustrated in Figure 1, which shows the simulated average and variable charges for different levels of consumption. Note that beneficiaries have a lower total average charge compared to non-beneficiaries, while the variable charge remains the same for both groups, except for households subject to the excess consumption surcharge. This gap in the average charges, absent in the variable charges, is what users take into account to adjust their consumption.

There is also some heterogeneity in the weight of the social tariff within the total bill across different beneficiaries. This weight depends on two factors: the level of consumption in the specific period and the 12-month moving average consumption, which determines the fixed charge on the bill. The Figure 2 illustrates the subsidy weight for monthly bills in 2021, defined as the ratio between the social tariff amount and the total amount billed. A negative relationship between consumption and the TSE weight is observed: bills with lower monthly consumption experience a greater relative impact of the subsidy, which decreases monotonically as consumption increases. Moreover, this weight is greater for bills in higher fixed charge categories.

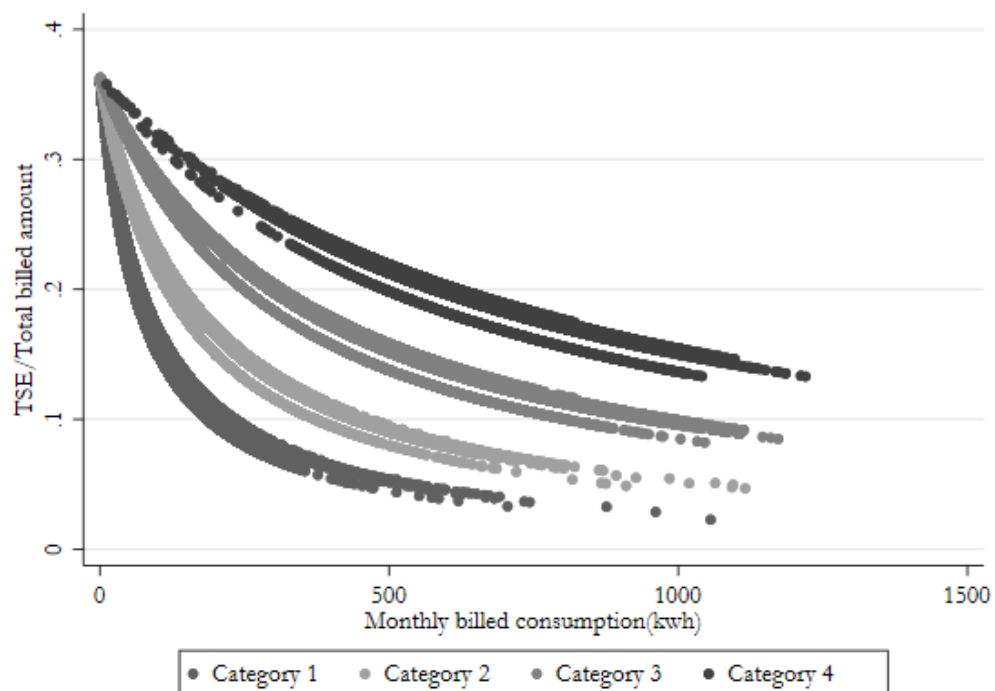
Figure 1: Average and marginal charge for residential electricity consumption in January 2021.



Source: Own elaboration based on the January 2021 chart in Table 2.

Note: Prices are simulated based assuming that monthly consumption is equal to the twelve-month average consumption. The grey dashed lines indicate the limits of the fixed charge categories.

Figure 2: Weight of the Social Electricity Tariff on the total amount billed for monthly bills issued in 2021, by fixed charge category.



Source: Own elaboration based on ERSEPT & EDET data.

Finally, it is important to mention that the fixed charge was updated in mid-April 2021 and the variable charge in August of the same year. In addition, the mechanism for allocating the subsidy has been modified as of January 2022. Unlike the previous system, in which the subsidy was allocated by the Energy Secretariat without user involvement, households are now required to apply for the subsidy.

In summary, the implementation of this energy policy by ERSEPT creates two different groups of residential users relevant to our research. On the one hand, there are the beneficiaries of the social tariff, i.e. vulnerable households that receive the subsidy and face a lower fixed charge regardless of their actual consumption level, which affects the total amount billed. On the other hand, there is a group of non-beneficiaries who, despite being in a vulnerable situation, do not receive the subsidy and therefore pay higher fixed charge. This distinction between groups and the exclusion of certain vulnerable households provides a strong framework for assessing how price differences influence energy consumption behaviour.

3 Methodology

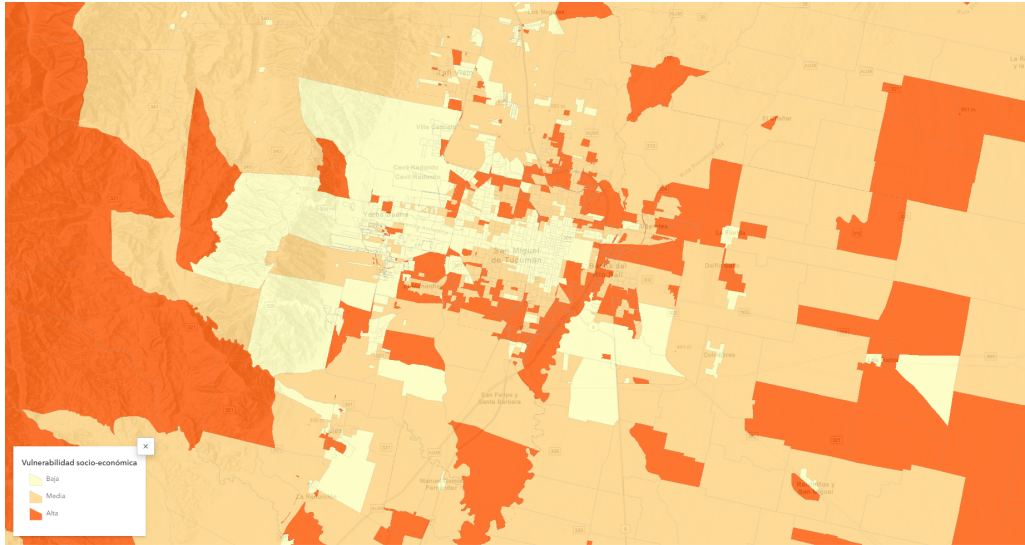
3.1 Identification strategy

3.1.1 The control group: High vulnerability zones

The Social Electricity Tariff was designed to benefit all households in vulnerable circumstances. Subsidies are allocated in accordance with a series of criteria that the service holder is required to meet. Nevertheless, a number of households were excluded from the program, either due to having outstanding debts with EDET or because the account holder did not fulfil any of the eligibility requirements, even if the residents of the household did. While the allocation strategy was not without imperfections, it is justified from a cost-benefit perspective. Individual variables can serve as a reliable proxy for household characteristics, and data collection is straightforward and standardised.

The question is: *how do we identify these excluded households?* ERSEPT, in collaboration with other institutions (ERSEPT, OFUT, DPE and MDP, 2018), designed an index to identify areas of socio-territorial vulnerability in the province. This was based on a multidimensional approach to the socioeconomic deprivations of the population, utilising data from the 2010 Population Census. The objective of its creation was, indeed, to improve the allocation of social tariffs for various public services. However, it should be noted that it was never used to assign the Social Electricity Tariff, which is the subject of our study.

Figure 3: Vulnerable zones in Gran San Miguel de Tucumán.



Source: ERSEPT, OFUT, DPE and MDP (2018). Available online at <https://storymaps.arcgis.com/stories/ee17538a984b4a3d8f1142268d49a45e>.

Our identification strategy leverages this particularity to find an appropriate control group, namely, those vulnerable households that were excluded from the subsidy allocation. The

index incorporates representative aspects⁸ of households as an aggregated unit, providing a key indicator for assessing households that, *a priori*, should receive the benefit. Thus, on one hand, there is the allocation of the Social Tariff, and on the other, the identification of high vulnerability zones, which aimed to better encompass those households that the TSE did not reach. Since this indicator was not used for allocation, it constitutes an exogenous variable for the identification of the control group.

Table 3: Comparison of the eligibility criteria for the social tariff and the variables used to define the vulnerable zones.

	Employment and Income	Housing	Education	Dependency
Variables include in Vulnerability Index				
% of heads of household w/basic education or less	✓		✓	
% of female heads of household w/basic education or less	✓		✓	
% of the population using a computer at home		✓		
Dependency ratio of the population aged 65 and older				✓
Ratio of children to women of childbearing age				✓
% of households without water provision inside		✓		
% of precarious housing (shack, hut)	✓	✓		
% of households with asset and convergent deprivation	✓	✓		
Social Electricity Tariff Eligibility Criteria				
Beneficiaries of AUH and Pregnancy Allowance	✓			✓
Beneficiaries of non-contributory pensions	✓			
Users of Social Monotax Scheme	✓			
Retirees and pensioners with income up to 2 LMW	✓			
Dependent workers with income up to 2 LMW	✓			
Self-employed with income up to 2 LMW	✓			
Unemployment insurance beneficiaries	✓			
Domestic workers with Social Security	✓			
Electrodependents				✓

Source: Resolution N°645/20 - RTI EDET S.A. 2020-2025 & ERSEPT, OFUT, DPE and MDP (2018).

Notes: AUH: Universal Child Allowance. LMW: Living Minimum Wage.

In Table 4, the distribution of beneficiaries of the social tariff according to the vulnerability of the areas in which they reside is presented. As can be observed, the beneficiaries of the

8. Variables encompassing various social, economic, environmental, and urban dimensions were included, highlighting the percentage of precarious housing (shacks, makeshift houses) and the percentage of households with material deprivation and convergent deprivation. Additionally, adjustments were made to the index using layers such as Informal Settlements or the Survey of Popular Neighborhoods (RENABAP). Furthermore, the obtained results were contrasted with other areas through spatial correlation analysis; such as households with Unsatisfied Basic Needs (INDEC), the Material Deprivation Index of Households (IPMH), among others.

subsidy are more numerous in areas of high vulnerability, and their participation decreases as vulnerability diminishes. Although they are not balanced, the presence of a common support in the high vulnerability segment allows for the subdivision of the sample into homogeneous groups to make a consistent comparison.

Table 4: Assignment of the Social Electric Tariff by Vulnerability Zone.

Vulnerability zone	Beneficiary*	Non-beneficiary**	Total
High	32,355 (67.51%)	15,569 (32.49%)	47,924 (100%)
Medium	10,420 (32.41%)	21,730 (67.59%)	32,150 (100%)
Low	5,605 (23.43%)	18,314 (76.57%)	23,919 (100%)
Not available data***	19 (79.17%)	5 (20.83%)	24 (100%)
Total	48,399 (46.53%)	55,618 (53.47%)	104,017 (100%)

Source: Own elaboration based on data from EDET & ERSEPT.

Notes: *Service receiving a social tariff in January 2021. **Service that never receives a social tariff. ***Due to the lack of location information for some services, there is a small group for which the data on the vulnerability of the zone they live in is not available.

3.1.2 Dif-in-Dif with two treatments

The comparability analysis discussed in the previous section is useful in this context. The natural experiment that occurred in Tucumán represents a particular case of difference-in-differences⁹ (DiD) due to the simultaneous introduction of two changes, or treatments: one group experienced a modification in the tariff scheme, while the other group observed this modification and additionally received the Social Tariff. Following the conceptual framework outlined by Fricke (2017), we designate these treatments as “high intensity” (with higher fixed charge) and “low intensity” (with lower fixed charge).

In scenarios where all individuals receive some type of treatment, the DiD estimator is used to compare the effect of one treatment relative to the other. Fricke (2017) and Callaway et al. (2024) demonstrate that, under certain assumptions, it is possible to fully or partially identify the average treatment effect on the treated (ATT). In particular, this identification requires a modification of the standard parallel trends assumption.

9. Fricke, H. (2017). Identification based on difference-in-differences approaches with multiple treatments. Oxford Bulletin of Economics and Statistics, 79(3):426–433.

Consider a high-intensity treatment and a low-intensity treatment, $d \in (H, L)$, and two groups of individuals, $D = H$ or $D = L$. In its simplest identification, we can consider the effects for each group separately with respect to an (unobserved) control group. We define $\Delta_{0L|D=L}$ as the ATT of treatment L for individuals in group L as:

$$\Delta_{0L|D=L} = \mathbb{E}[Y_1^L | D = L] - \underbrace{\mathbb{E}[Y_1^0 | D = L]}_{\text{Counterfactual}} \quad (1)$$

Where $\mathbb{E}[Y_1^L | D = L]$ represents the potential outcome of an individual in group L at time $t = 1$, having received treatment L .

In this case, identification requires the standard parallel trends (PT) assumption:

$$\mathbb{E}[Y_1^L | D = L] - \mathbb{E}[Y_0^0 | D = L] = \mathbb{E}[Y_1^0 | D = 0] - \mathbb{E}[Y_0^0 | D = 0] \quad (2)$$

In our case, the causal effect on individuals in the group L is defined as:

$$\Delta_{HL|D=L} = \mathbb{E}[Y_1^L | D = L] - \underbrace{\mathbb{E}[Y_1^H | D = L]}_{\text{Counterfactual}} \quad (3)$$

In this case, the required PT assumption is:

$$\mathbb{E}[Y_1^H | D = L] - \mathbb{E}[Y_0^0 | D = L] = \mathbb{E}[Y_1^H | D = H] - \mathbb{E}[Y_0^0 | D = H] \quad (4)$$

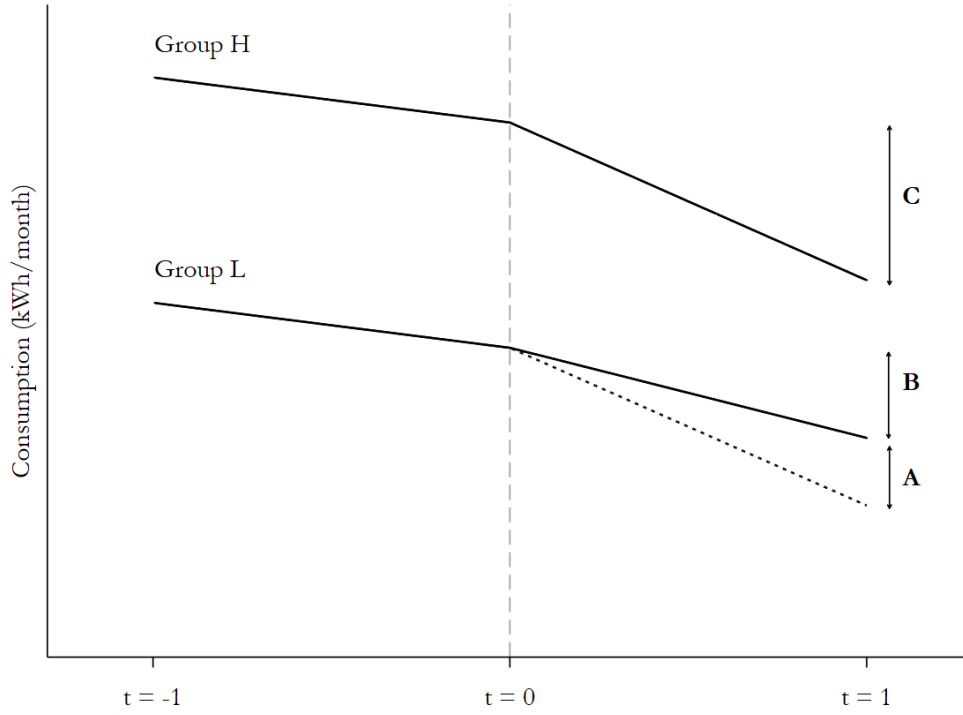
$$\underbrace{\mathbb{E}[Y_1^H | D = L]}_{\text{Counterfactual}} = \underbrace{\mathbb{E}[Y_1^H | D = H]}_{\text{Identified}} - \underbrace{\mathbb{E}[Y_0^0 | D = H]}_{\text{Identified}} + \underbrace{\mathbb{E}[Y_0^0 | D = L]}_{\text{Identified}} \quad (5)$$

Note that the right side of equation (4) indicates the trend in consumption for individuals who did not receive the Social Electricity Tariff and faced the tariff change, while the left side indicates the trend that *would have been observed* among beneficiaries had they not received the subsidy and *had faced* the full tariff increase. In general terms, the equation implies that the parallel trends assumption will hold if and only if the high treatment (H) has homogeneous effects across both groups. In our case, this requires assuming that the tariff change would have had the same effect on both groups in the absence of the Social Tariff. If this holds, then our DiD estimator represents the ATT of the electricity tariff subsidy,¹⁰ by substituting equation 4 into 3:

$$\underbrace{\Delta_{HL|D=L}}_A = \underbrace{\mathbb{E}[Y_1^L | D = L] - \mathbb{E}[Y_0^0 | D = L]}_B - \underbrace{(\mathbb{E}[Y_1^H | D = H] - \mathbb{E}[Y_0^0 | D = H])}_C \quad (6)$$

10. Callaway, B., Goodman-Bacon, A., and Sant'Anna, P. H. (2024). Difference-in-differences with a continuous treatment. Technical report, National Bureau of Economic Research.

Figure 4: Causal effect in DiD with two treatments of differing intensity and parallel trends.



Notes: The lines show the observed consumption for each group, and the dashed line represents the unobserved consumption for group L if it had received treatment H. References A, B, and C correspond to equation 6.

Moreover, in the context of our study, we assume a demand model in which users adjust their consumption based on the last price observed on their bill.¹¹ If users lack complete information and respond in this manner,¹² it is expected that no significant treatment effect will be observed in the first period after the tariff changes, i.e., January. By this period reading, users have yet to receive any bill under the new tariff scheme. In February, the second period, consumers refer to the price from the previous month, when the tariff change had not fully applied. By the end of this period, they observe the full effect of the new tariff.¹³

3.2 Data

For this analysis, we use as our main source a panel of billing data for all residential users in the province, provided by ERSEPT.¹⁴ This dataset includes more than 13 million bills, corresponding to 562,866 residential users in Tucumán for the period January-2019 to June 2022. Of these users, 151,580 have a monthly billing cycle and 411,286 have a bi-monthly billing

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11. Wichman, C. J. (2014). Perceived price in residential water demand: Evidence from a natural experiment. *Journal of Economic Behavior & Organization*, 107:308–323.
 12. For other studies involving imperfect information, see Ito (2014); Bastos et al. (2015) For a theoretical discussion, refer to Liebman (2004).
 13. Note that this applies to monthly users whose meter reading occurs during the last ten days of the month.
 14. It is important to note that data of this calibre are not publicly available and are provided through an institutional confidentiality agreement between the research team, EDET and ERSEPT.

cycle. Each registered bill includes data such as service number, energy consumption, meter reading date, amount billed, user’s social tariff status and details of bill payment behaviour.

Prior to the analysis, we applied a number of restrictions to the data. First, we select only monthly billers, excluding bimonthly billers. Bimonthly users have their meters read throughout the month, whereas monthly users only in the last days of the month. These differences between billing cycles have a significant impact on the timing of when households receive their bill and observe new prices. This results in several scenarios for the timing and intensity of treatment for bi-monthly users. Due to the complexity of the scenario, we decided to focus the analysis only on monthly users who receive their last bill with old prices in December, a bill with prorated prices in January and bills with new prices from February onwards.

Second, we limit the analysis to the years 2020 and 2021, as a change in the subsidy allocation mechanism was introduced in January 2022, requiring households to apply voluntarily to become beneficiaries.

Third, we exclude users with irregular behaviour, such as those whose service was cancelled during the analysis period, those with at least one bill with zero consumption, those with more than one reading per month or those with extreme consumption belonging to the 99th percentile of the monthly consumption distribution.

Finally, services that were assigned the social tariff at any point after January 2021, as well as those whose subsidy had been withdrawn, were excluded from the analysis. It should be noted that the majority of beneficiaries receive the subsidy at the time of application and do not lose it during the analysis period. Conversely, only 302 users lost their beneficiary status and 421 users received the subsidy late.

Moreover, in order to adhere to our identification strategy, we keep only those households situated within the high vulnerability zone. Finally, the database used consists of over one million monthly bills corresponding to 2020 and 2021, associated with 47,924 users, of which 67.51% receive the social tariff in January 2021.

Table 5: Filtered database observations, by Social Tariff condition.

	Beneficiaries*	Non-beneficiaries**	Total
Households	32,355	15,569	47,924
Bills	776,520	373,656	1,150,176
	(67.51%)	(32.49%)	(100.00%)

Source: Own elaboration based on data from EDET & ERSEPT.

Notes: *Service that receives the social tariff in January 2021. **Service that does not receive the social tariff at any time.

3.3 Model

To perform the estimation, we start with the model presented in equation 7:

$$\ln(C_{it}) = \beta_0 + \beta_1 post_t + \beta_2 post_t \cdot TSE_i + \beta_3 MA_{it} + \alpha_i + \varepsilon_{it} \quad (7)$$

Where:

- C_{it} is the monthly electricity consumption of household i in period t .
- $post_t$ is a binary variable equal to 1 for observations corresponding to the year 2021 (post-treatment), and 0 otherwise.
- TSE_i is a binary variable equal to 1 if household i is a beneficiary of the Social Electricity Tariff, and 0 otherwise.
- MA_{it} is the 12-month moving average of consumption prior to t for household i .
- α_i : fixed effects for household i .
- ε_{it} is the idiosyncratic error.

The parameter of interest in our analysis is β_2 , which represents the average treatment effect on the treated (ATT) associated with the implementation of the subsidy. This parameter is expected to have a positive sign, given the difference in prices faced by the two groups: one with high prices and the other with low prices. While both types of prices tend to reduce consumption, the intensity of the increase in the control group is greater. Under normal conditions, it is reasonable to assume that the price reaction will be equal to or greater in the group facing high prices compared to the low-price group. Thus, when calculating the difference, a positive effect on consumption is expected for those users who access the subsidized tariff.

4 Results

This section presents the results of our analysis, focusing on the Average Treatment Effect on the Treated and the heterogeneous effects observed across different consumption levels. We begin by detailing the impact of the subsidy on highly vulnerable households' consumption, followed by an exploration of how these effects vary across different consumption categories and quintiles. Finally, we calculate the price elasticity of demand for electricity, providing insights into consumer responsiveness to price changes.

Estimations were conducted for the months of January to December 2021, with December 2020 as the reference month. Given that January represents the initial period preceding the introduction of the subsidy, we call it $t=1$.

4.1 Average treatment effect on the treated

The first regression, presented in Table 6, shows the estimates from the standard model for all users in vulnerable households. The results display a positive and significant effect of the TSE in all analysed periods, with an increase in consumption ranging from around 1.19% (Regression N°2) to 9.84% (Regression N°9).

A noteworthy outcome of our analysis is that the parameter is not statistically significant during the period of subsidy implementation ($t=1$). Subsequently, the effect increases in both significance and magnitude by the third period ($t=3$). This is consistent with our demand model, where consumers do not respond to the current or expected price, but instead adjust their consumption based on the last observed tariff. Additionally, the positive and significant sign in the remaining months reflects the fact that users responded to changes in the average charge rather than the marginal charge.

Table 6: Average Treatment Effect of Social Tariff on beneficiaries' consumption. Short and Long Term estimates.

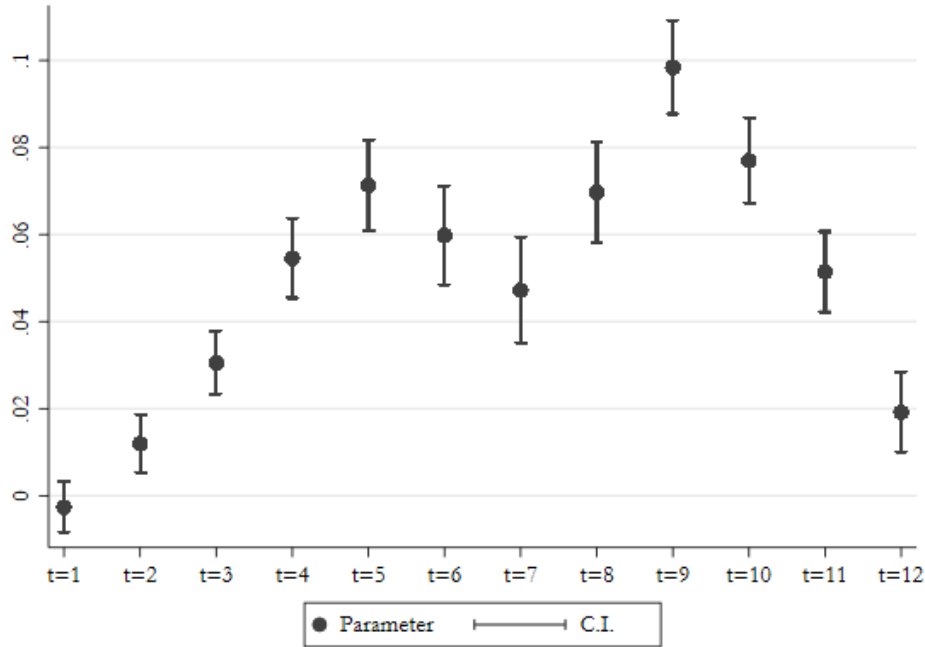
	<i>Dependent Variable: $\ln(\text{consumption}_t)$</i>					
	t=1	t=2	t=3	t=4	t=5	t=6
	(1)	(2)	(3)	(4)	(5)	(6)
<i>post</i>	-0.0396*** (0.0026)	-0.1687*** (0.0030)	-0.1881*** (0.0032)	-0.3836*** (0.0041)	-0.5028*** (0.0045)	-0.3074*** (0.0049)
<i>post</i> $\times$ <i>TSE</i>	-0.0026 (0.0029)	0.0119*** (0.0034)	0.0305*** (0.0037)	0.0546*** (0.0047)	0.0714*** (0.0053)	0.0598*** (0.0058)
MA	0.0063*** (0.0002)	0.0040*** (0.0001)	0.0032*** (0.0001)	0.0037*** (0.0001)	0.0037*** (0.0001)	0.0039*** (0.0001)
β_0	3.9046*** (0.0456)	4.5142*** (0.0336)	4.7201*** (0.0264)	4.5907*** (0.0259)	4.6038*** (0.0257)	4.5506*** (0.0240)
Average consumption	310	270	267	217	198	248
Households	47,924	47,924	47,924	47,924	47,924	47,924
Observations	95,848	95,848	95,848	95,848	95,848	95,848
Within R^2	0.115	0.285	0.264	0.450	0.486	0.275

	<i>Dependent Variable: $\ln(\text{consumption}_t)$</i>					
	t=7	t=8	t=9	t=10	t=11	t=12
	(7)	(8)	(9)	(10)	(11)	(12)
<i>post</i>	-0.3401*** (0.0053)	-0.4363*** (0.0050)	-0.5423*** (0.0046)	-0.3153*** (0.0043)	-0.1907*** (0.0040)	-0.0491*** (0.0040)
<i>post</i> $\times$ <i>TSE</i>	0.0472*** (0.0062)	0.0697*** (0.0059)	0.0984*** (0.0055)	0.0770*** (0.0050)	0.0514*** (0.0047)	0.0192*** (0.0047)
MA	0.0038*** (0.0001)	0.0035*** (0.0001)	0.0028*** (0.0001)	0.0026*** (0.0001)	0.0026*** (0.0001)	0.0029*** (0.0000)
β_0	4.5763*** (0.0216)	4.6537*** (0.0190)	4.8462*** (0.0165)	4.8878*** (0.0147)	4.8915*** (0.0138)	4.8231*** (0.0131)
Average consumption	242	219	194	239	270	306
Households	47,924	47,924	47,924	47,924	47,924	47,924
Observations	95,848	95,848	95,848	95,848	95,848	95,848
Within R^2	0.297	0.390	0.494	0.456	0.426	0.290

Notes: Robust standard errors in parentheses. Fixed effects at the service level. MA is calculated as the moving average of consumption for the last twelve months of the user. The period t=1 corresponds to the first month prior the implementation of the Social Tariff. *** p<0.01, ** p<0.05, * p<0.1.

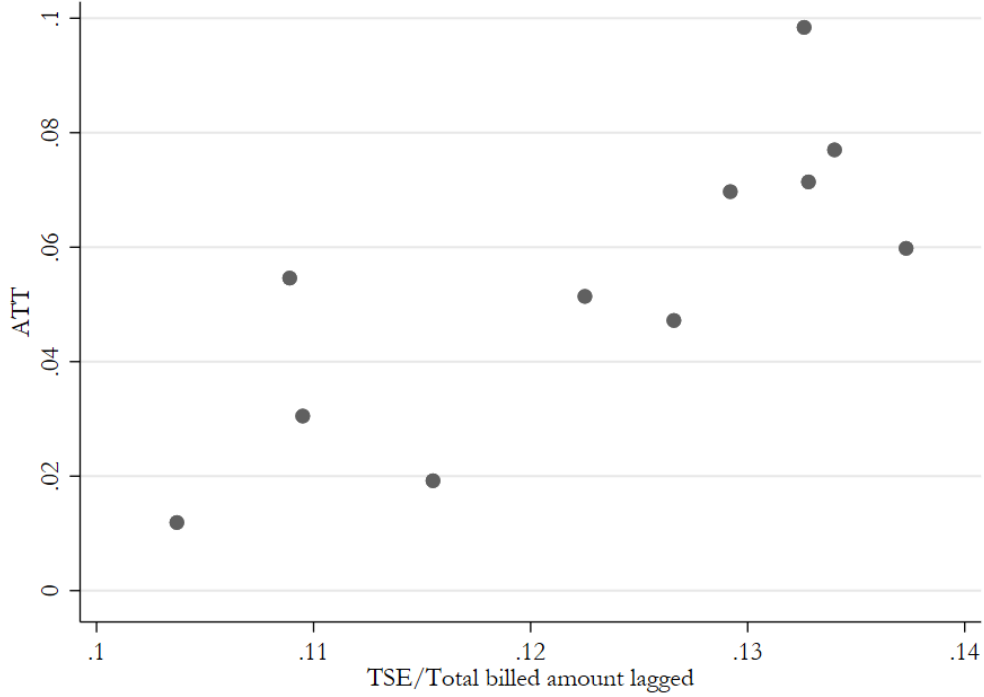
The Figure 5 summarizes the results of the short- and long-term regressions corresponding to Table 6. As previously explained, the coefficients are positive and significantly different from zero for all periods, except for the first one. Additionally, a clear oscillating pattern is observed, with peaks in periods five and nine, corresponding to the months of May and September.

Figure 5: Estimated ATT and confidence intervals of the basic model estimates.



This variability could be attributed to the heterogeneity in treatment intensity among users: due to the tariff structure, the impact of the subsidy on the total billed amount depends on both the level of consumption in the specific period and the 12-month moving average consumption (Figure 2). During periods of lower consumption, such as in autumn and spring months, the subsidy has a greater weight in the bill. Users observe greater price differences on their bills during these months; therefore, we expect that once these prices are observed, the higher subsidy weight in the tariff will significantly impact consumption in the following period. Figure 6 clearly shows a positive linear relationship between the average treatment effect and the treatment intensity of the previous period, represented by the weight of the social tariff in the bill.

Figure 6: Estimated ATT and weight of the Social Electric Tariff in the billed amount lagged on period.



4.2 Heterogeneous effects

It is noteworthy that the impact of a change in prices also varies according to the user's consumption level (Wichman, 2014). Therefore, we use the consumption category variables and the household average consumption quintile to delve into the heterogeneous effects of this policy. The category is defined in section 2. Regarding the second variable, the average consumption for 2020 was calculated for each user, and they were assigned to their corresponding quintile in the distribution. Since users within the same quintile exhibited similar consumption patterns in 2020, it is reasonable to assume they share unobservable characteristics that influence their consumption. Thus, these variables allow for better simultaneous control of the comparison groups while providing information about treatment heterogeneity. As seen in Tables A.2 and A.3 in the appendix, the allocation of the TSE is balanced across the different quintiles and consumption categories.

Tables 7, 8, and 9 present the results of the estimations across different consumption segments, organized by quintile or category. These results demonstrate a notable heterogeneity in the treatment effect among the various groups. In particular, the magnitude of the impact is greater in the medium consumption segments, both by category and quintile, and decreases for higher levels. Simultaneously, the effects in the low consumption segments are not significant in most of the analysed months. This could be explained by the fact that households with very low consumption are already at the limit of their energy capacity, or because, in these cases, the preference for increasing electricity consumption is lower compared to the consumption of

other goods (Wichman, 2014).

In Table 7, we observe that when dividing the sample according to quintile groups, the effect is greater in quintiles 2, 3, and 4. For March 2021, for example, a positive and significant effect of between 4.60% and 2.14% in consumption is apparent for quintiles 2 to 5, with no significance observed in most months for the first quintile.

Table 7: Average effect of the social tariff on beneficiaries by consumption quintile.

Period	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
t=1	-0.0059	-0.0018	0.0050	-0.0059	-0.0012
t=2	-0.0063	0.0153**	0.0222***	0.0119*	0.0108*
t=3	0.0149	0.0460***	0.0355***	0.0263***	0.0214***
t=4	0.0211	0.0556***	0.0645***	0.0627***	0.0468***
t=5	0.0356**	0.0812***	0.0743***	0.0817***	0.0559***
t=6	0.0298*	0.0915***	0.0588***	0.0745***	0.0324***
t=7	0.0084	0.0680***	0.0568***	0.0697***	0.0279**
t=8	0.0319*	0.0770***	0.0838***	0.0910***	0.0525***
t=9	0.0738***	0.1039***	0.1022***	0.1009***	0.0758***
t=10	0.0558***	0.0748***	0.0823***	0.0855***	0.0624***
t=11	0.0318**	0.0672***	0.0573***	0.0555***	0.0381***
t=12	0.0158	0.0301***	0.0198**	0.0295***	0.0110

Notes: The quintile group was assigned to each user based on the average consumption distribution for 2020. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Tables 8 and 9 highlight the differences between users belonging to different consumption categories, where we observe a similar dynamic: the first category ($MA \leq 150$ kWh) does not exhibit significant effects, except for periods outside peak times, where the treatment weight is greater.

Table 8: Average effect of the social tariff on beneficiaries by fixed charge category.

Period	Category 1	Category 2	Category 3	Category 4
t=1	-0.0070	0.0050	0.0012	0.0182*
t=2	-0.0039	0.0214***	0.0170***	0.0425***
t=3	0.0140	0.0403***	0.0323***	0.0168
t=4	0.0191	0.0545***	0.0631***	0.0621***
t=5	0.0333**	0.0782***	0.0764***	0.0692***
t=6	0.0327*	0.0725***	0.0596***	0.0562***
t=7	0.0042	0.0687***	0.0544***	0.0471*
t=8	0.0307*	0.0662***	0.0763***	0.0702***
t=9	0.0730***	0.0889***	0.0901***	0.0696***
t=10	0.0605***	0.0763***	0.0791***	0.0660***
t=11	0.0372**	0.0709***	0.0512***	0.0417***
t=12	0.0250	0.0352***	0.0272***	0.0171

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 9: Average effect of the social tariff on beneficiaries controlling for the average consumption over the last twelve months, by fixed charge category.

Period	Category 1	Category 2	Category 3	Category 4
t=1	-0.0060	0.0022	-0.0038	0.0206**
t=2	-0.0060	0.0177***	0.0103**	0.0422***
t=3	0.0112	0.0368***	0.0256***	0.0197
t=4	0.0172	0.0501***	0.0528***	0.0633***
t=5	0.0316**	0.0747***	0.0654***	0.0689***
t=6	0.0291*	0.0681***	0.0484***	0.0529**
t=7	0.0025	0.0638***	0.0448***	0.0416*
t=8	0.0261	0.0618***	0.0663***	0.0643***
t=9	0.0684***	0.0854***	0.0819***	0.0650***
t=10	0.0519***	0.0701***	0.0695***	0.0616***
t=11	0.0285*	0.0650***	0.0419***	0.0368**
t=12	0.0125	0.0262***	0.0155***	0.0105

Notes: The fixed charge categories are defined based on the moving average consumption over the last twelve months. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

4.3 Price elasticity

To estimate the price elasticity of demand, it is essential to use data corresponding to the same time period, including consumption, tariff, and social tariff (TSE). The underlying logic of the estimation is to compare, through the coefficient β_2 , the impact that a subsidy beneficiary would have faced had they encountered high prices, that is, those received by non-beneficiaries. Thus, the percentage change in price is defined as:

$$\Delta\%P(\bar{c}_t) = \frac{P_{TSE,t}}{P_t} - 1 = -\frac{TSE_t}{P_t} \quad (8)$$

Where P_t is the high tariff, $P_{TSE,t}$ is the tariff with subsidy, and TSE_t is the amount of subsidy, all in period t . It turns out that the change in prices due to the implementation of the social tariff is equal to the negative of what we previously defined as the weight of the subsidy in the bill. To calculate it, we first define the average consumption of the households in the corresponding sample at t , $\bar{c}_t$. Given that there are four different treatment intensities for the same level of consumption, one for each fixed charge category, we used the average of these. Thus, the price elasticity η can be calculated as the ratio between the estimated coefficient $\hat{\beta}_t$ and the average percentage change in price:

$$\eta = \frac{\hat{\beta}_{2,t}}{\Delta\%P(\bar{c}_t)} \quad (9)$$

Table 10 shows that the price elasticity of electricity consumption calculated for all households is inelastic, taking values between -0.12 and -0.5, with -0.19 in the short term and -0.12 in the long term. It is important to note that these elasticities may be lower during the summer months, such as in $t=3$ and $t=12$, which correspond to March and December, due to the limited ability of households to substitute electricity with natural gas, as gas is not a viable alternative for cooling during this season. In contrast, during the winter months, households have more options to reduce electricity consumption by switching to gas for heating purposes, which could lead to higher elasticity values.

When analysing the results by consumption quintile, detailed in Table 11, we observe that in the first period, elasticity varies between -0.18 to -0.31 for the different quintiles.¹⁵ By December, the behaviour remains inelastic, although the reaction to prices is lower, with statistically significant values ranging between -0.15 and -0.24.

15. Not considering the group belonging to quintile N°1, as the treatment effect is not statistically different from zero at the 10% significance level.

Table 10: Price elasticity of electricity.

Period	$\bar{c}$	$\Delta\% P$	$\hat{\beta}_2$	η
t=3	267	-15.8%	0,0305***	-0.19
t=4	217	-19.4%	0,0546***	-0.28
t=5	198	-19.8%	0,0714***	-0.36
t=6	248	-18.2%	0,0598***	-0.33
t=7	242	-19.6%	0,0472***	-0.24
t=8	219	-19.1%	0,0697***	-0.36
t=9	194	-19.7%	0,0984***	-0.50
t=10	239	-18.1%	0,0770***	-0.43
t=11	270	-17.1%	0,0514***	-0.30
t=12	306	-15.9%	0,0192***	-0.12

Notas: * $p < 0,1$, ** $p < 0,05$, *** $p < 0,01$.

Table 11: Price elasticity of electricity according to consumption quintile.

Period	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
t=3	-0.09	-0.31	-0.24	-0.18	-0.18
t=4	-0.10	-0.31	-0.35	-0.34	-0.29
t=5	-0.16	-0.41	-0.37	-0.41	-0.34
t=6	-0.12	-0.47	-0.32	-0.44	-0.22
t=7	-0.35	-0.55	-0.53	-0.58	-0.49
t=8	-0.13	-0.40	-0.44	-0.51	-0.32
t=9	-0.36	-0.54	-0.53	-0.51	-0.42
t=10	-0.30	-0.44	-0.48	-0.47	-0.41
t=11	-0.16	-0.42	-0.35	-0.33	-0.28
t=12	-0.06	-0.23	-0.17	-0.24	-0.15

5 Robustness check

To assess the robustness of our findings, we conducted a falsification test by simulating a treatment that was applied one year prior to the actual implementation of the social tariff. In an ideal scenario, we would expect the treatment effect to be null, indicating that there are no confounding influences affecting our results during this pre-treatment period. However, the results of our analysis, presented in Table A.4 of the appendix, show that while the estimated treatment effects are lower than what we observe in the actual treatment period (see Figure A.1), we can reject the null hypothesis that they are statistically equal to zero for all periods except the last one.

This suggests that there may be underlying factors influencing electricity consumption that are not fully accounted for within our model. The observation of non-zero treatment effects, even in the pre-treatment period, may indicate that external factors or prevailing trends influenced household consumption patterns during this time.

An assumption to consider here is that the confounder in question would have maintained the same pre-trend magnitude in treatment year¹⁶. Under this assumption, our estimates would provide an upper bound for the true effect of the TSE on beneficiaries.

Therefore, while our primary results still hold, this analysis underscores areas that warrant further investigation.

16. This approach aligns with a simplified perspective within a broader literature on Differences-in-Differences estimations, particularly in cases where the parallel trends assumption may not strictly hold. See Ram-bachan and Roth (2023)

6 Conclusions

This study estimates the short- and long-term price elasticity of residential energy consumption using a natural experiment derived from the implementation of the Social Electricity Tariff in Tucumán, Argentina. This policy, aimed at assisting vulnerable households, provided a subsidy for the fixed charge of the electricity rate. A differences-in-differences approach is employed, using non-beneficiary households of the social tariff as the control group. This allows us to calculate the price elasticity of electricity consumption at different consumption levels.

The results obtained in this study reveal that the implementation of the Social Electricity Tariff generated a positive impact on residential consumption, with an average increase of 3.05% in the short term and 1.92% in the long term. The price elasticity of demand remained negative and inelastic throughout the analysed period, with values ranging from -0.12 to -0.50. This behaviour suggests that the policy had a moderate, yet consistent, effect on reducing consumption, aligning with previous estimates evidenced in (Labandeira et al., 2017).

An important aspect of this analysis is that no significant impact on household consumption is observed during the month of January, which indicates that consumers tend to react with a certain lag to changes in prices. This could be due to frictions in information acquisition or inertia in consumption patterns, suggesting that decisions are based on the perception of previous prices rather than immediate adjustments. This is supported by evidence provided by Wichman (2014) and also addressed by Ito (2014).

Another key finding in this regard is that households appear to respond to the average price rather than the marginal price, which is consistent with previous studies that have demonstrated how information costs and the complexity of tariff structures hinder consumers' ability to perceive and react to marginal prices (Liebman, 2004). In particular, Ito (2014) shows that both marginal price elasticity and expected marginal price elasticity are not significantly different from zero, while average price elasticity is significant. This reinforces the idea that subsidy schemes, such as the TSE, which primarily affect the fixed charges of the tariff (and thus average prices), may be effective in inducing changes in consumer behaviour.

In terms of heterogeneity, notable differences are observed in consumer responses according to their consumption levels. Households in the first quintile or consumption category did not show a significant reaction to the implementation of the TSE, which may be explained by their limitations in adjusting consumption, as these households are likely at the maximum threshold of energy use due to constraints in durable goods or a low preference for increasing consumption of such goods. On the other hand, households in the second to fourth quintiles exhibited more pronounced responses, with elasticities ranging from -0.18 to -0.31 in the short term, and from -0.17 to -0.24 in the long term.

This work represents a significant contribution to the limited body of literature on price elasticity of energy demand in Latin America, particularly in the context of quasi-experimental

studies. As emphasized by Labandeira et al. (2017), estimates of energy elasticities in the region are scarce, highlighting the importance of continuing research in this field to better understand the dynamics of energy demand and to design more effective policies.

Finally, it is crucial to consider that although the TSE is designed to improve the welfare of vulnerable households, its effectiveness may be limited compared to other schemes. Firstly, users appear to react less to price decreases than to increases (Peersman and Wauters, 2024), suggesting that such subsidies may not be the optimal mechanism for enhancing welfare in these households. Alternatively, as suggested by Schaffitzel et al. (2020), strengthening assistance programs through direct transfers could have a more effective impact. Moreover, tariff policies aimed at *reducing* consumption through pricing may not be entirely effective, as consumer responses are often limited. In this regard, there is literature on alternative *non-pricing* responses, such as modifying information presentation, appealing to social norms, or promoting investment in durable goods to achieve a sustained effect over time (Schultz et al., 2007; Sudarshan, 2017; Allcott and Rogers, 2014).

Future research in Argentina should focus on analysing the behaviour of non-vulnerable households, an area not covered in this study, but essential both for reducing the environmental impact of energy consumption and for analysing the distributive effects of tariff changes. Furthermore, the inherent complexity of tariff designs and the heterogeneous reactions of consumers pose a challenge for the accurate estimation of price elasticity of demand, reinforcing the need to implement energy policies in experimental contexts that allow for a more rigorous and precise evaluation of their impacts.

References

- Allcott, H. and Rogers, T. (2014). The short-run and long-run effects of behavioral interventions: Experimental evidence from energy conservation. *American Economic Review*, 104(10):3003–3037.
- Bastos, P., Castro, L., Cristia, J., and Scartascini, C. (2015). Does energy consumption respond to price shocks? evidence from a regression-discontinuity design. *The Journal of Industrial Economics*, 63(2):249–278.
- Berndt, E. R. and Samaniego, R. (1984). Residential electricity demand in mexico: a model distinguishing access from consumption. *Land Economics*, 60(3):268–277.
- Callaway, B., Goodman-Bacon, A., and Sant’Anna, P. H. (2024). Difference-in-differences with a continuous treatment. Technical report, National Bureau of Economic Research.
- ERSEPT, OFUT, DPE and MDP (2018). Zonas de vulnerabilidad socioterritorial para la asignación de tarifa social de servicios públicos en la provincia de tucumán. informe técnico y desarrollo cartográfico [en línea].
- Fricke, H. (2017). Identification based on difference-in-differences approaches with multiple treatments. *Oxford Bulletin of Economics and Statistics*, 79(3):426–433.
- Houthakker, H. S. (1951). Some calculations on electricity consumption in great britain. *Journal of the Royal Statistical Society. Series A (General)*, 114(3):359–371.
- Inter-american Development Bank (2020). How do households consume energy? evidence from latin american and caribbean countries. Consultado el 1 de noviembre de 2024.
- International Energy Agency (2021). Net zero by 2050. Licence: CC BY 4.0.
- Ito, K. (2014). Do consumers respond to marginal or average price? evidence from nonlinear electricity pricing. *American Economic Review*, 104(2):537–563.
- Labandeira, X., Labeaga, J. M., and López-Otero, X. (2017). A meta-analysis on the price elasticity of energy demand. *Energy policy*, 102:549–568.
- Liebman, J. B. (2004). Schmeduling jeffrey b. liebman and richard j. zeckhauser harvard university and nber.
- Nataraj, S. and Hanemann, W. M. (2011). Does marginal price matter? a regression discontinuity approach to estimating water demand. *Journal of Environmental Economics and Management*, 61(2):198–212.
- Peersman, G. and Wauters, J. (2024). Heterogeneous household responses to energy price shocks. *Energy Economics*, 132:107421.

- Phoumin, H. and Kimura, S. (2014). Analysis on price elasticity of energy demand in east asia: Empirical evidence and policy implications for asean and east asia. *ERIA discussion paper series*, 5:1–26.
- Poblete-Cazenave, M. and Pachauri, S. (2021). A model of energy poverty and access: Estimating household electricity demand and appliance ownership. *Energy Economics*, 98:105266.
- Rambachan, A. and Roth, J. (2023). A more credible approach to parallel trends. *Review of Economic Studies*, 90(5):2555–2591.
- Schaffitzel, F., Jakob, M., Soria, R., Vogt-Schilb, A., and Ward, H. (2020). Can government transfers make energy subsidy reform socially acceptable? a case study on ecuador. *Energy Policy*, 137:111120.
- Schultz, P. W., Nolan, J. M., Cialdini, R. B., Goldstein, N. J., and Griskevicius, V. (2007). The constructive, destructive, and reconstructive power of social norms. *Psychological science*, 18(5):429–434.
- Sudarshan, A. (2017). Nudges in the marketplace: The response of household electricity consumption to information and monetary incentives. *Journal of Economic Behavior & Organization*, 134:320–335.
- Wichman, C. J. (2014). Perceived price in residential water demand: Evidence from a natural experiment. *Journal of Economic Behavior & Organization*, 107:308–323.
- Zhang, Z., Cai, W., and Feng, X. (2017). How do urban households in china respond to increasing block pricing in electricity? evidence from a fuzzy regression discontinuity approach. *Energy Policy*, 105:161–172.
- Zou, H., Luan, B., Zheng, X., and Huang, J. (2020). The effect of increasing block pricing on urban households’ electricity consumption: Evidence from difference-in-differences models. *Journal of Cleaner Production*, 257:120498.

A Tables and figures

Table A.1: Summary of Literature Review

Author (Year)	Service	Elasticity (%)	Region	Methodology
Labandeira et al. (2017)	Electricity	-0.13 (ST), -0.37 (LT)	Meta-analysis (Global)	Meta-analysis
Ito (2014)	Electricity	-0.054 (ST), -0.088 (LT)	USA (California)	RD
Zou et al. (2020)	Electricity	Reduction in kWh	China (3 cities)	DD
Zhang et al. (2017)	Electricity	-0.87	China (Guangdong)	RD
Nataraj and Hanemann (2011)	Water	-0.012	USA (California)	RD
Wichman (2014)	Water	-0.43 to -1.14	USA (C.N.)	DD, DDD, RD*
		-0.06 to -1.53	SEA and AO	
		-0.22; -0.38	Australia	
Phoumin and Kimura (2014)	TFEC** and TFOC***	-0.10; -0.12	Japan	Dynamic log-linear
		positive ^a	China	
		-0.06; -0.15	India	
		-0.12; -0.35	Philippines	
		-0.35; -1.7	Singapore	
		-0.16; -1.53	Thailand	

Source: Own elaboration.

Notes: *Differences in differences (DD), Triple differences (DDD), Regression discontinuity (RD). ***Total Final Energy Consumption*. ****Total Final Oil Consumption*. ^a *Authors noted that a structural demand shock not accounted for by their model occurred in China during the evaluation period, which biased their estimations.*

Table A.2: Assignment of the social electricity tariff by average consumption quintile for the year 2020.

Quintile	Beneficiary*	Non-beneficiary**	Total
1	6,727 (70.11%)	2,868 (29.89%)	9,595 (100%)
2	6,730 (70.24%)	2,851 (29.76%)	9,581 (100%)
3	6,593 (68.77%)	2,994 (31.23%)	9,587 (100%)
4	6,292 (65.70%)	3,285 (34.30%)	9,577 (100%)
5	6,013 (62.74%)	3,571 (37.26%)	9,584 (100%)
Total	32,355 (67.51%)	15,569 (32.49%)	47,924 (100%)

Source: Own elaboration based o EDET & ERSEPT data.

Notes: *Service receiving a social tariff in January 2021. **Service not receiving a social tariff at any time.

Table A.3: Bills assignment on the social electricity tariff by fixed charge category.

Fixed charge category	Beneficiary*	Non-beneficiary**	Total
1	179,988 (70.02%)	77,074 (29.98%)	257,062 (100%)
2	254,859 (69.46%)	112,063 (30.54%)	366,922 (100%)
3	315,069 (65.18%)	168,348 (34.82%)	483,417 (100%)
4	26,604 (62.20%)	16,171 (37.80%)	42,775 (100%)
Total	776,520 (67.51%)	373,656 (32.49%)	1,150,176 (100%)

Source: Own elaboration based o EDET & ERSEPT data.

Notes: *Service receiving a social tariff in January 2021. **Service not receiving a social tariff at any time.

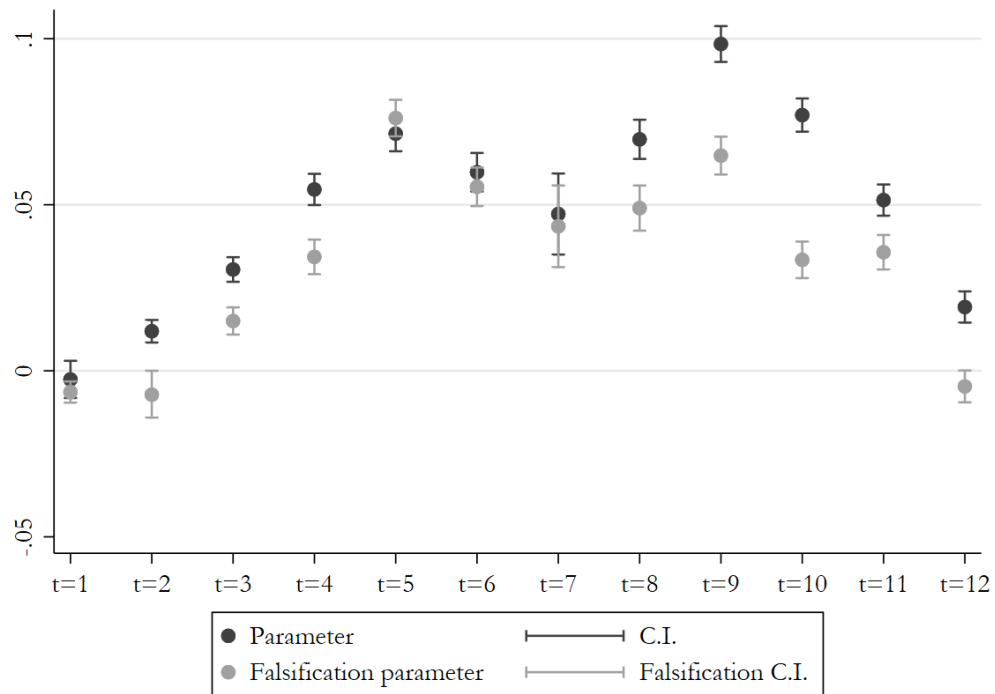
Table A.4: Falsification Test. Average effect of the Social Tariff on the beneficiaries' consumption.

	<i>Dependent Variable: $\ln(\text{consumption}_t)$</i>					
	t=1	t=2	t=3	t=4	t=5	t=6
	(1)	(2)	(3)	(4)	(5)	(6)
<i>post</i>	0.1700*** (0.0030)	0.1007*** (0.0032)	-0.0297*** (0.0037)	-0.1955*** (0.0046)	-0.5345*** (0.0048)	-0.2513*** (0.0050)
<i>post</i> $\times$ <i>TSE</i>	-0.0064** (0.0032)	-0.0072** (0.0035)	0.0150*** (0.0041)	0.0343*** (0.0052)	0.0761*** (0.0055)	0.0554*** (0.0058)
MA	0.0083*** (0.0002)	0.0042*** (0.0001)	0.0020*** (0.0001)	0.0026*** (0.0001)	0.0002** (0.0001)	0.0010*** (0.0001)
β_0	3.3995*** (0.0430)	4.4474*** (0.0304)	4.9942*** (0.0280)	4.8287*** (0.0262)	5.4279*** (0.0243)	5.2347*** (0.0219)
Households	46,459	46,459	46,459	46,459	46,459	46,459
Obs.	92,918	92,918	92,918	92,918	92,918	92,918
Within R^2	0.355	0.153	0.015	0.094	0.436	0.115

	<i>Dependent Variable: $\ln(\text{consumption}_t)$</i>					
	t=7	t=8	t=9	t=10	t=11	t=12
	(7)	(8)	(9)	(10)	(11)	(12)
<i>post</i>	-0.2196*** (0.0054)	-0.3737*** (0.0049)	-0.4310*** (0.0049)	-0.1383*** (0.0043)	-0.2111*** (0.0045)	0.0482*** (0.0042)
<i>post</i> $\times$ <i>TSE</i>	0.0435*** (0.0063)	0.0490*** (0.0058)	0.0648*** (0.0057)	0.0334*** (0.0049)	0.0357*** (0.0052)	-0.0047 (0.0048)
MA	0.0021*** (0.0001)	0.0019*** (0.0001)	0.0019*** (0.0001)	0.0023*** (0.0001)	0.0028*** (0.0001)	0.0033*** (0.0001)
β_0	4.9578*** (0.0210)	5.0051*** (0.0186)	5.0211*** (0.0169)	4.9215*** (0.0146)	4.7962*** (0.0146)	4.6604*** (0.0130)
Households	46,459	46,459	46,459	46,459	46,459	46,459
Obs.	92,918	92,918	92,918	92,918	92,918	92,918
Within R^2	0.083	0.248	0.305	0.090	0.156	0.200

Notes: Robust standard errors in parentheses. Fixed effects at the service level. Period t=1 corresponds to January 2020, simulating that the implementation of the Social Tariff took place in that period. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Figure A.1: Real estimated ATT vs falsification estimated ATT.



Note: Estimates corresponding to the regressions presented in Tables 6 and A.4.