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The Hidden Costs of Tariff Misclassification

STRUCTURAL WINNERS AND LOSERS

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Abstract

We propose an empirical model to evaluate firms' choices in electric tariff contracting. By combining novel data from the Non-residential Electricity Consumption Survey (ENCENRE) with utility billing data from the national utility company, we analyze two pathological situations revealed by the electric bills of commercial and service SMEs in Aguascalientes, Mexico, during 2019 and 2020. First, despite being banned, many firms pay the residential tariff. Among these firms, some pay the regular subsidized rate, while others pay the high-demand rate, which is higher than the corresponding business rate. Additionally, for another group of companies, there are two competing business tariffs, many of which are misclassified and thus must be re-categorized to afford less expensive electric bills. A rich set of explanatory variables is used to quantify the two biases, explain the wrong decisions, estimate hidden costs and subsidies at the national level, and provide valuable policy implications.

Keywords: tariff misclassification, firm behavior, electricity consumption, self-selection, suboptimal choice, illegal behavior.
JEL Codes: L1, Q4, D22.

Resumen

Proponemos un modelo empírico para evaluar las decisiones de las empresas en la contratación de tarifas eléctricas. Al combinar datos novedosos de la Encuesta de Consumo Eléctrico No Residencial (ENCENRE) con datos de facturación de servicios públicos de la empresa eléctrica nacional, analizamos dos situaciones patológicas reveladas por las facturas de electricidad de las PYME comerciales y de servicios en Aguascalientes, México, durante 2019 y 2020. Primero, a pesar de estar prohibidas, muchas empresas pagan la tarifa residencial. Entre estas empresas, algunas pagan la tarifa regular subsidiada, mientras que otras pagan la tarifa de alta demanda, que es más alta que la tarifa comercial correspondiente. Además, para otro grupo de empresas, hay dos tarifas comerciales en competencia, muchas de las cuales están mal clasificadas y, por lo tanto, deben recategorizarse para permitir facturas eléctricas menos costosas.

Se utiliza un cuantioso conjunto de variables explicativas para cuantificar los dos sesgos, explicar las decisiones equivocadas, estimar los costos ocultos y los subsidios a nivel nacional y proporcionar valiosas implicaciones de política.

Palabras clave: clasificación errónea de tarifas, comportamiento de firmas, consumo de electricidad, autoselección, elección subóptima, comportamiento ilegal.
Códigos JEL: L1, Q4, D22.

The Hidden Costs of Tariff Misclassification: Structural Winners and Losers

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August 8, 2024

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We propose an empirical model to evaluate firms' choices in electric tariff contracting. By combining novel data from the Non-residential Electricity Consumption Survey (ENCENRE) with utility billing data from the national utility company, we analyze two pathological situations revealed by the electric bills of commercial and service SMEs in Aguascalientes, Mexico, during 2019 and 2020. First, despite being banned, many firms pay the residential tariff. Among these firms, some pay the regular subsidized rate, while others pay the high-demand rate, which is higher than the corresponding business rate. Additionally, for another group of companies, there are two competing business tariffs, many of which are misclassified and thus must be re-categorized to afford less expensive electric bills. A rich set of explanatory variables is used to quantify the two biases, explain the wrong decisions, estimate hidden costs and subsidies at the national level, and provide valuable policy implications.

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1 Introduction

Utilities such as electricity, natural gas, water, and sewerage often apply different rates for various user types, including residential, commercial, industrial, and agricultural. Ideally, these tariff schemes should be tailored to the specific needs of each user type, encouraging efficient resource use. Additionally, tariffs should cover the full cost of service,[1] support network expansion and ensure a fair return on investment.[2]

Moreover, users often select a tariff from a list of options for future periods, which can vary widely. For example, cell phone users may choose from pay-as-you-go plans and monthly or yearly contracts and can select between phone-only plans or various bundled deals. Similarly, industrial users of natural gas may opt for firm (uninterruptible) or interruptible contracts, with the latter being less expensive but involving greater risk and variability in supply.[3] Electricity rates also vary, with some being flat tariffs and others being time-of-use tariffs.[4] Additionally, electricity users can choose from different tariff categories based on factors such as contracted power or connected load.

From the perspective of a social planner, if the regulator could design tariff schemes to eliminate consumers' informational rents, consumers would select rates as if they were assigned the appropriate tariff type, thus maximizing economic surplus. A similar logic applies to investor-owned utilities if they could set prices to maximize their profits (Besanko and Spulber, 1992; Segal and Whinston, 2002).[5] In practice, regulated utilities may attempt to influence the regulator to set service rates based on (stated) differential costs. The regulator may even face political pressure to subsidize certain sectors, with policies that are sometimes populist in nature (Hancevic, Cont, and Navajas, 2016). The whole process is

[1] The full cost of service encompasses production, transmission/transportation, distribution, and commercialization. For water services, it also includes treatment.

[2] Cost recovery objectives are often influenced by other goals (Batlle, Mastropietro, and Rodilla, 2020; Hancevic, Nuñez, and Rosellón, 2022). In some emerging countries, cross-subsidy mechanisms are used among different user types or direct subsidies are provided for access to and consumption of certain services—particularly water, electricity, and gas—in the residential and agricultural sectors (Hancevic et al., 2016; McRae and Wolak, 2021; Chattopadhyay, 2004; Hancevic et al., 2022). Tariff structures may also incorporate environmental and conservation policies, such as increasing block pricing for residential water (Kulshreshtha, 1996; Olmstead, Hanemann, and Stavins, 2007) or price differentiation based on the type of energy source used for electricity generation (Sundt and Rehdanz, 2015).

[3] In the Argentine industrial sector, firm gas contracts guarantee uninterrupted service except in emergencies or cases of force majeure. In contrast, interruptible contracts allow for service interruptions, provided the gas distribution company gives prior notice. Most gas distribution services are firm, except for interruptible distribution and interruptible transportation services, which are specifically designed as interruptible contracts.

[4] For example, in California, households and farmers can choose from a range of electricity tariffs with different combinations of fixed charges and rates per kWh, and can also select their electricity meter type (conventional vs. smart meter).

[5] This would result in the same economic surplus but with a different distributional outcome.

somewhat heuristic. Regulators face challenges such as incomplete and imperfect information, costly monitoring, incomplete contracts, and political pressures when designing tariff schedules. These issues have been theoretically discussed since Laffont and Tirole (1993). However, identifying how these factors influence tariff design is an empirical issue, as common theoretical elements like participation and incentive compatibility constraints are often overlooked in practice.

Furthermore, assumptions about consumer behavior and rationality are often inadequately addressed, making the self-selection process, typically described in textbooks as a straightforward interaction between tariffs and consumers (Viscusi, Harrington Jr, and Sappington, 2018), much more complex. Traditional assumptions about consumer characteristics—such as economic rationality, attitudes toward uncertainty, discounting, foresight, cost minimization, and consistency of preferences—may not hold in practice (Kőszegi, 2014). When consumers' cognitive abilities and preferences are more accurately considered, they often lead to tariff choices that differ from those predicted by utilities. This discrepancy raises important questions about whether consumers are selecting tariffs based on a flawed understanding of the regulatory framework or if they are choosing the tariffs that minimize their expected monthly bills, given their consumption patterns.

In addition, insufficient monitoring and enforcement can allow some users to exploit the system by choosing tariffs intended for different categories. For example, a small firm operating from a residential building might opt for a residential electricity tariff, which is often illegal and subject to penalties if detected. This problem is particularly acute in many emerging countries, where residential tariffs are heavily subsidized. In such cases, firms benefiting from these subsidized rates can divert resources away from low-income households, worsening inequities and straining public resources.

Considering these complexities, the interaction between tariffs and consumer choices can lead to three potential outcomes:

1. *Optimal tariff choice*: Ideally, consumers select the tariff that minimizes their service costs while matching their usage type. For instance, households would choose residential rates, businesses would opt for business rates, and agricultural producers would select rural rates. This outcome reflects a well-functioning system where tariffs align with consumer needs and usage patterns. As Friesen and Earl (2015) find, knowledgeable users who understand pricing mechanisms are better equipped to make optimal choices.

2. *Unintentional misclassification*: In some cases, consumers might unintentionally select suboptimal tariffs. This can occur due to factors such as rational inattention, complex-

ity of tariff menus, bounded rationality, adherence to norms, or imperfect information. Such misclassifications result in higher costs for consumers who are not fully aware of or able to navigate the available options effectively. For instance, Hortaçsu, Madanizadeh, and Puller (2017) explores how choice frictions, including a preference for the incumbent's brand name, can diminish the benefits of retail choice for residential electricity users in Texas. Consumers unfamiliar with the power to choose may not seek better options or switch to new entrants, resulting in missed opportunities for cost savings.

3. *Illegal misclassification*: In other instances, consumers might deliberately exploit the system by choosing a tariff category for which they do not qualify. For example, a small firm operating from a residential building might opt for a residential electricity tariff, which is often illegal.

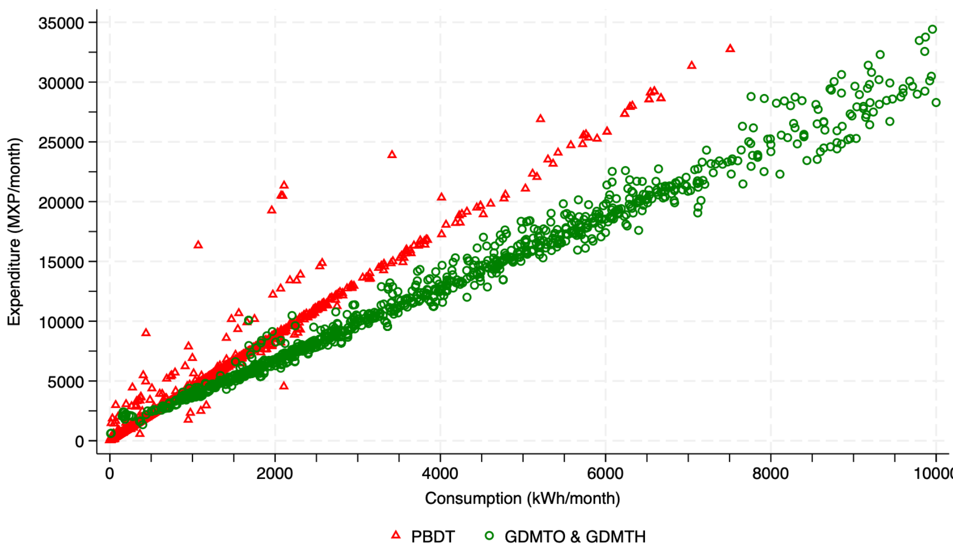
In this paper, we propose a model to enhance our understanding of electric tariff choices among small and medium-sized commercial and service enterprises (SMEs) in the Metropolitan Area of Aguascalientes, Mexico. We use novel firm-level data from the Non-residential Electricity Consumption Survey (ENCENRE-2019), supplemented by billing records from the national utility company (*Comisión Federal de Electricidad, CFE*), to empirically investigate the factors influencing tariff selection and the associated hidden costs.[6] Considering the complexities in tariff selection, we analyze two key scenarios. First, we examine instances where firms incur higher electricity costs due to selecting an incorrect business rate (*unintentional misclassification*), which may result from either over-sizing or under-sizing their required load. Second, we investigate cases where firms choose a tariff that does not match their user type (*illegal misclassification*), choosing a residential rate instead of a business rate. Figure 1 illustrates these issues by plotting electricity consumption (kWh/month) against electricity expenditure in Mexican Pesos per month (MXP/month).

Panel A depicts the scenario of unintentional misclassification. It shows two competing business tariffs: the low-voltage tariff (PDBT) and the medium-voltage tariffs (GDMTO and GDMTH). For firms with consumption levels exceeding 1,000 kWh/month, the figure highlights that many have chosen the incorrect tariff. In these cases, re-categorization to a different rate could reduce their electricity costs.

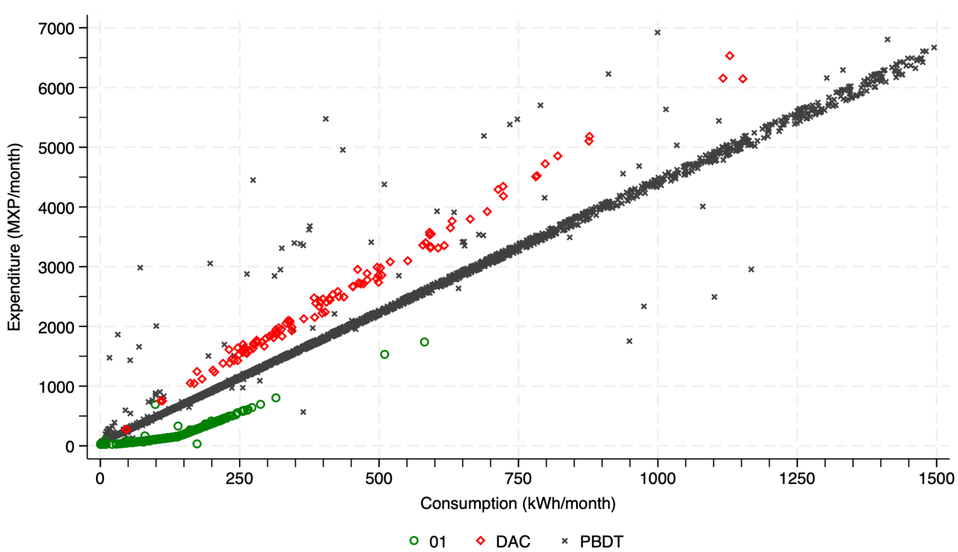
[6] The ENCENRE provides a representative sample of small and medium-sized businesses operating in the Metropolitan Area of Aguascalientes.

Figure 1: Electricity Consumption and Expenditure of SMEs in the Aguascalientes Metropolitan Area: March 2019 - February 2020

(a) Unintentional Misclassification



(b) Illegal Misclassification



The scatter plots show monthly electricity consumption in kWh (horizontal axis) and monthly expenditure in Mexican pesos (vertical axis) for users with different competing tariffs. The low voltage tariffs are the residential tariffs O1 and DAC, and the business tariff PBDT. The medium-voltage tariffs are GDMTO and GDMTH, which correspond to high demand without and with a peak load pricing, respectively. See Table 1 and 2 for a description of the tariffs. Source: CFE Billing data from the firms participating in the ENCENRE-2019.

Panel B addresses the issue of illegal misclassification, where a non-trivial number of

SMEs opt for residential tariffs despite this being prohibited. The residential tariff structure in Mexico is complex: it includes a subsidized increasing block tariff (01 tariff) and a two-part tariff for high-demand residential users (DAC tariff) that applies once an annual consumption threshold is exceeded. Interestingly, the panel shows that among firms using the residential tariff, some pay less compared to the appropriate business rate (PDBT), while others pay more. At very low consumption levels, the residential tariff 01 is cheaper than the PDBT business tariff. However, beyond ∼250 kWh per month, the PDBT becomes more cost-effective compared to the DAC high-demand residential rate.

Our results indicate that firm characteristics such as business size, operating days, business sector, and equipment type significantly influence the choice of electricity tariffs. Specifically, we found that medium-sized businesses operating seven days per week and with air conditioning and specialized equipment tend to select suboptimal tariffs. This suggests that the higher demand for continuous operation throughout the week and the use of high-demand electrical equipment leads to a suboptimal tariff choice. In contrast, businesses selecting residential tariffs tend to occupy office spaces and operate predominantly in the service sector, which includes professional, scientific, and technical services. These types of businesses typically operate in buildings that resemble residential structures such as houses or apartments, and their electricity needs might mirror those of residential households. This similarity likely explains why they adopt a residential tariff despite it being illegal for businesses to do so.

Moreover, our results reveal that there are significant hidden costs associated with this tariff misclassification problem. Suboptimal tariff choices lead to increased electricity costs, which directly impact firms' overall expenditures and profitability. Specifically, we identified an excess spending of 27.9 million Mexican Pesos (MXP) per year due to suboptimal tariffs. At the national level, this amounts to 3 billion MXP per year in higher costs.

Additionally, when SMEs improperly use residential electricity tariffs and benefit from household subsidies, it misallocates resources, inflates public spending, creates market distortions, and fosters unfair competition. Our calculations indicate that firms in Aguascalientes receive 58.6 million MXP in subsidies annually, while those on the residential DAC tariff incur an excess cost of 1 million MXP. As a result, the net (improper) subsidy received by these firms at the national level is estimated to be over 6.4 billion Mexican Pesos per year, representing approximately 8% of the total budget approved to subsidize electricity rates for all types of uses in 2023. This practice not only increases electricity consumption and exacerbates environmental issues but also undermines policies intended to support vulnerable households.

This paper leverages firm-level data from a developing country to investigate electric tariff misclassification, making significant contributions to the literature. First, it fills a notable gap by empirically studying the factors influencing suboptimal and illegal tariff choices among small and medium-sized businesses. To the best of our knowledge, this topic has not been explored empirically in prior research. Second, we systematically identify the factors associated with these choices, providing insights into why firms adopt suboptimal tariffs and highlighting the characteristics of businesses opting for residential (illegal) tariffs. Finally, our analysis underscores the potential gains from improved tariff decision-making, emphasizing the significant welfare implications and the impact on resource allocation and operational costs.

The rest of the paper is organized as follows. Section 2 describes the context, discussing the metro areas and the tariff schemes. Section 3 provides a model of the optimal private decision-making. Section 4 describes the data and provides summary statistics for the main variables used in the analysis. Section 5 reports the main results regarding the determinants of tariff misclassification. Section 6 discusses the associated hidden costs at the state and national levels. Finally, Section 7 offers concluding remarks.

2 Tariff Schemes for SMEs in Mexico

We focus on small- and medium-sized enterprises (SMEs) in Aguascalientes Metropolitan Area.[7] In our sample, there are three main groups of tariffs: residential tariffs (categories 01 and DAC), low-demand at low-voltage business tariffs (PDBT), and high-demand at medium-voltage business tariffs (GDMTO and GDMTH). Table 1 provides a list of tariff acronyms for reference, and Table 2 shows the electricity rates for October 2019.[8]

The residential tariff 01 is a three-tier increasing block pricing scheme with no fixed charge. All users who contract the residential rate are initially classified as 01. However, if their consumption surpasses the threshold of 3,000 kWh during the past year, they are automatically reclassified as high-demand residential customers and are subject to the DAC tariff. Notice that the variable charge in the DAC category is considerably higher than the highest marginal price in the 01 category. Therefore, depending on the sum of kWh from the current bill plus the kWh from the previous five bills (totaling a year of consumption), a user can be classified as 01 or DAC. Although it is possible to switch back to 01 from DAC, there are no such cases in our sample.

PDBT is the simplest business tariff, with a two-part tariff with fixed and volumetric

[7]Aguascalientes is a mid-size metropolitan area representative of the central region of Mexico with a population of 1.14 million in 2020.

[8]The analysis is based on a survey administered between May and October 2019, supplemented by billing records spanning from January 2019 to March 2020. This dataset is also used in Hancevic and Sandoval (2023) to study the adoption decisions of solar panels among SMEs in Aguascalientes.

charges. In contrast, the two high-demand business tariffs, GDMTO and GDMTH, include capacity and distribution charges. The latter distinguishes between base, intermediate, and peak hours, so variable charges are set accordingly.

Table 1: List of Electricity Tariff Acronyms

Acronym	**Meaning**
Residential rates	
01	Residential tariff
DAC	High-demand residential tariff
Business rates	
PDBT	Low demand at low voltage
GDMTO	High demand at medium voltage without peak-load pricing (ordinary)
GDMTH	High demand at medium voltage with peak-load pricing

This table provides the acronyms of the different tariffs used throughout the document. Source: State-owned national electric utility (Comisión Federal de Electricidad, CFE).

Table 2: Electricity Rates in Aguascalientes for October 2019

A. Residential rates						
01		Variable				
		(0-150 kWh)	(151-280 kWh)	(+ 281 kWh)		
		0.043	0.052	0.151		
DAC	Fixed	Variable				
	5.637	0.242				
B. Business rates						
PDBT	Fixed	Variable				
	2.343	0.177				
GDMTO	Fixed	Variable	Capacity	Distribution		
	24.134	0.066	14.203	4.980		
GDMTH		Variable				
	Fixed	Base	Intermediate	Peak	Capacity	Distribution
	23.431	0.048	0.085	0.096	17.577	4.914

This table shows the electricity rates in October 2019. All values are in U.S. Dollars; the exchange rate is 19.25 MXP/USD. The fixed charges are expressed in USD per billing period; variable charges (i.e., volumetric) are expressed in USD per kWh; and capacity and distribution charges are expressed in USD per kW. Source: State-owned national electric utility (Comisión Federal de Electricidad, CFE).

3 The model

In this section, we introduce the model, beginning with the description of the energy demand function. In period t, the firm's energy consumption level e_t depends on the firm's economic activity level y_t, its stock of energy-intensive appliances and equipment s_t, the energy price p_t, and other characteristics and demand drivers captured in the vector $\mathbf{x}$—i.e., control variables.[9] The demand function has the form:

$$e_t = f(p_t, y_t, \mathbf{s_t}, \mathbf{x_t}; \theta) + \varepsilon_t \tag{1}$$

where θ is a vector of parameters and ε is the structural error term that captures the unobserved heterogeneity and any possible measurement error. Suppose there are (at least) two competing tariffs that meet the typical electricity consumption needs of the firm. For simplicity, let's call them tariff A and tariff B, so the firm compares energy expenditure under each tariff, that is, whether,

$$T^A(e_t) \quad \lesseqgtr \quad T^B(e_t) \tag{2}$$

For most companies in our study, energy usage remains consistent throughout the year (see Figure 2). Therefore, energy consumption expectations should be computationally feasible, and a profit maximizing firm contracts service by comparing expected expenditure under different tariffs. If the expected expenditure associated with contracting under tariff A is below the corresponding expenditure associated with tariff B, $T^A(E(e_t)) < T^B(E(e_t))$, then the firm chooses tariff A, otherwise it chooses tariff B.

To make this choice more concrete, in our case, a SME could contrast the PDBT tariff with the GDMTO/GDMTH tariffs mentioned in the previous section. This comparison, however, should also include the annualized cost of the investment in facilities necessary to operate at low or medium voltage (e.g., wiring, installations, and transformers), which, for generality (and simplicity), we assume depends on a certain function of expected consumption:

$$T^{PDBT}(E(e_t)) + C^{PDBT}(E(e_t)) \lesseqgtr T^{GDMTO}(E(e_t)) + C^{GDMTO}(E(e_t)) \tag{3}$$

As discussed before, the GDMTO tariff also includes a capacity and distribution charges

[9] For the moment, we left aside the discussion on whether firms respond to average or marginal electricity prices. For empirical evaluations on this topic, see Ito (2014) and Nataraj and Hanemann (2011), which present mixed evidence.

(in \$ per kW). Both are two-part tariffs with a fixed charge, F^j, and a marginal price, P^j

$$T^j(e_t) = F^j + P^j \cdot e_t \quad \text{for all } e_t \geq 0 \quad \text{and with } j = \text{PDBT, GDMTO} \tag{4}$$

The other competing tariff category is the residential tariff scheme, originally designed for households. The context in this case is different as it involves users with relatively low consumption. Hence, medium voltage tariffs (GDMTO and GDMTH) are not in the choice set. In the residential tariff scheme, there are two potential situations that depend on a threshold condition. These situations involve comparing a function of the current electricity consumption to a critical value, $g(e_t) \leq \bar{\bar{e}}$. This function could be a summary measure of both current and past electricity consumption. In our case, it is the average consumption in the last 12-month period, including the current bill, $g(e_t) = 1/6 \sum_{k=0}^{5} e_{t-k}$. For expository purposes, we can think of a residential tariff as follows:

$$T_t^R(e_t) = \begin{cases} \text{LD}(e_t) & \text{if } g(e_t) \leq \bar{\bar{e}} \\ \text{HD}(e_t) & \text{if } g(e_t) > \bar{\bar{e}} \end{cases} \tag{5}$$

Hence, when $g(e)$ falls below the threshold $\bar{\bar{e}}$, the consumer faces the low-demand residential tariff (LD), otherwise she pays the high-demand residential tariff (HD). We can think of LD as the regular residential tariff and HD as the penalized residential tariff. As it is typically the case, the regular residential tariff is an increasing block pricing (IBP) scheme. Here, we illustrate an IBP with three consumption blocks:

$$\text{LD}(e_t) = \begin{cases} F_t^L + p_{1t}^L \cdot e_t & \text{if } 0 \leq e_t \leq \bar{e}_1,\ g(e_t) \leq \bar{\bar{e}} \\ F_t^L + p_{1t}^L \cdot \bar{e}_1 + p_{2t}^L \cdot (e_t - \bar{e}_1) & \text{if } \bar{e}_1 \leq e_t \leq \bar{e}_2,\ g(e_t) \leq \bar{\bar{e}} \\ F_t^L + p_{1t}^L \cdot \bar{e}_1 + p_{2t}^L \cdot \bar{e}_2 + p_{3t}^L \cdot (e_t - \bar{e}_1 - \bar{e}_2) & \text{if } \bar{e}_2 \leq e_t,\ g(e_t) \leq \bar{\bar{e}} \end{cases}$$

where $\bar{e}_i$ for $i = 1, 2$ represents the size of the consumption block i. The high-demand tariff is simply a two-part tariff of the form

$$HD(e) = F_t^H + p_t^H \cdot e_t \quad \text{for all } e_t > 0 \text{ such that } g(e_t) > \bar{\bar{e}}$$

The firm chooses which tariff contract, and in the decision process what matters are the relative marginal prices and the fixed charges of the competing tariff categories, the consumption threshold, and the expected energy consumption. Another important element in the decision is whether there is a penalty for contracting the residential tariff and the corresponding chance of getting caught. We include this additional cost related to the residential tariff as a function of total consumption, $\Gamma(e_t)$. In the Mexican case, a non-trivial situation occurs since $p^{DAC} > p^{PDBT} > p_3^L > p_2^L > p_1^L \geq 0$ and $F^{DAC} > F^{PDBT} > F^L = 0$ where p are the volumetric charges for DAC, PDBT and 01 tariffs, respectively, and similarly, F are the corresponding fixed charges. Hence, a rational firm adopts a tariff contract that minimizes the expected cost. For instance, it chooses the business regime (PDBT) if

$$T^{PDBT}(E(e)) \leq LD(E(e|e \leq \bar{\bar{e}})) \cdot Pr(e \leq \bar{\bar{e}}) + HD(E(e|e > \bar{\bar{e}})) \cdot Pr(e > \bar{\bar{e}}) + E\left[\Gamma(e)\right] \quad (6)$$

3.1 Econometric specification

The structural model from the previous section helps us understand the problem each firm faces when selecting the electricity tariff, whether in a low or medium-high-consumption context. We assume that firms make discrete decisions and that the random component (i.e., the error term) follows a Type 1 Extreme Value distribution. Therefore, the probability that the firm i makes a suboptimal (or a residential) tariff choice j is given by

$$Pr(\text{Tariff=j}|V_j) = \frac{exp(V_j\delta)}{\sum_k exp(V_k\delta)} \quad (7)$$

where V_k is the vector of characteristics of the firm and the variables describing the tariff j. Equation 7 corresponds to a logistic (logit) model. We estimate the parameters of this model, δ, using maximum likelihood estimation and robust standard errors.[10] The set of variables included in the vector $\boldsymbol{V}$ are presented in Table 3.

4 Data and Summary Statistics

The empirical analysis is based on a representative sample of small and medium-sized businesses operating in the Metropolitan Area of Aguascalientes, Mexico. Each business is matched to its corresponding billing data from the state-owned national electric utility (*Comisión Federal de Electricidad, CFE*).

4.1 Business survey

Sponsored by the Mexican Ministry of Energy and the National Science and Technology Council, researchers at the Center for Research and Teaching in Economics conducted the Non-Residential Electricity Consumption Survey (ENCENRE) in the Aguascalientes

[10] In Appendix Appendix B, we present ordinary least squares (OLS) estimates corresponding to the linear probability model.

Metropolitan Area between May and October of 2019.[11] The survey aimed to characterize establishments based on their electricity consumption, providing detailed information on business economic activities, building characteristics, air conditioning, heating, stock of electrical equipment, energy conservation practices, and environmental attitudes. This survey data is complemented by billing records from the Mexican national electricity utility, covering the period from January 2019 to March 2020. We excluded 30 businesses with multiple utility bills (service numbers) and different tariffs for the analysis. Our final working sample includes complete information for 720 businesses.

Table 3 reports summary statistics for the variables used in our analysis. All variables are binary except for the (log) number of employees. Our primary outcomes of interest are suboptimal tariff choice and residential (illegal) tariff choice variables. The *suboptimal tariff choice* variable is a dummy variable indicating whether the tariff selected by the business is suboptimal. A choice is deemed suboptimal if switching from one tariff scheme to another (e.g., from PDBT to GDMTO) would lead to lower electricity expenditures. To construct this variable, we considered only establishments under business rates (i.e., we excluded those under residential tariffs). Additional details on the construction of this variable are provided in Appendix A. Notably, the table shows that approximately 24.8% of businesses could benefit from a tariff change. We further categorize the suboptimal choice into *suboptimal PDBT* and *suboptimal GDMT* choices. The former category refers to businesses that have chosen a PDBT (low-demand at low voltage) tariff but would benefit from switching to a GDMTO (high-demand at medium voltage) tariff, while the latter involves businesses that would benefit from switching from GDMTO/H to a PDBT tariff.[12] The majority of suboptimal businesses, approximately 92%, fall into the first category, benefiting from a switch from PDBT to GDMTO.

The second outcome variable, *residential tariff choice*, is a dummy indicating whether the tariff selected by the business is a residential tariff. For this outcome, we restrict the analysis to businesses under low-voltage tariffs (01, DAC, and PDBT), as those under medium-voltage tariffs (GDMTO/H) have different needs and are not typically deciding between residential or business tariffs. Around 10.3% of businesses under low-voltage tariffs opt for a residential (illegal) tariff.

As shown in the table, approximately 8.9% of businesses have a residential tariff (01 and DAC), 77.5% have a low demand at a low-voltage tariff (PDBT), and the remaining 13.6% have a high demand at medium-voltage tariff (GDMTO/H). Furthermore, most

[11] See Hancevic, Bejarano, Nuñez, and Rosellon (2019) for additional details. The ENCENRE-2019 dataset is available at https://hancevic.weebly.com/original-data-sets.html

[12] None of the PDBT businesses in our sample would benefit from switching to GDMTH, hence we focus our analysis on those firms for which the optimal switch is from PDBT to GDMTO changes.

businesses are located within one of the three municipalities comprising the metro area of Aguascalientes.[13]

To understand the factors related to choosing a suboptimal and residential (illegal) tariff, we included a range of variables such as firm and building characteristics, equipment inventory, electricity consumption variability, and behavioral factors. Summary statistics for these variables are also presented in Table 3.

Regarding firm characteristics, the variables included business size, ownership status, operating days per week, and sector classification. As shown in the table, most businesses are small-sized, and nearly half operate within the service sector.[14] Additionally, only 31.5% own their premises, and 27.5% operate seven days per week. We anticipate that ownership of the premises will be a relevant factor influencing tariff choice, as renters might face higher costs or encounter difficulties in changing tariffs. On the other hand, property owners typically have more flexibility in adjusting electricity usage patterns and investing in energy-efficient upgrades, which can impact their tariff decisions. Similarly, regarding business size, we expect that larger businesses will operate more optimally due to their likelihood of being equipped with dedicated technicians and robust electrical installations. In contrast, smaller businesses are more prone to errors and, given their size, are also inclined to adopt residential rates. In terms of building characteristics, most buildings are attached to others (93.6%), with only a small fraction having insulation in roofs, walls, or windows (10.7%) and having undergone renovations since 2000 (12.1%). While the reported renovations mostly involve structural changes such as removing walls, interior remodeling, adding rooms, and even constructing second floors, some may impact electrical installations and prompt a revision of tariff selection. Additionally, approximately one-fifth of these buildings primarily use their space for offices. Moreover, only 35% of businesses are equipped with air conditioning, which is unsurprising given the typically favorable climate conditions in Aguascalientes, with temperatures ranging between 39°F and 86°F.

Regarding the stock of equipment, a large majority of the businesses have office equipment such as computers and printers (87.6%), along with other appliances like TVs or kitchen-related appliances (61.8%). Fewer possess specialized equipment like servers (36.5%) or commercial refrigerators (24.7%). Nonetheless, this specialized equipment, often tied to their operational needs, can lead to higher-than-expected electricity consumption, potentially

[13] The Aguascalientes metropolitan area includes the municipalities of Aguascalientes, Jesús María, and San Francisco de los Romo, with establishments distributed as 95.1%, 4.5%, and 0.4%, respectively.

[14] Business size was determined according to definitions from the National Institute of Geography and Statistics (INEGI). Small-sized businesses are defined as having fewer than ten employees. Medium-sized businesses are categorized as having between 11 and 30 employees in the trade sector and between 11 and 50 employees in the service sector. Large-sized businesses exceed these thresholds in their respective sectors.

resulting in a mismatched tariff selection.

Table 3: Survey Data: Summary Statistics

	Mean	Std. Dev.	N
Suboptimal tariff choice	0.248	(0.432)	656
Suboptimal PDBT	0.229	(0.420)	656
Suboptimal GDMTO/H	0.020	(0.139)	656
Residential (illegal) tariff choice	0.103	(0.304)	622
Tariff:			
01	0.065	(0.247)	720
DAC	0.024	(0.152)	720
PDBT	0.775	(0.418)	720
GDMTO	0.115	(0.320)	720
GDMTH	0.021	(0.143)	720
Aguascalientes municipality	0.951	(0.215)	720
Firm characteristics			
Business size (# of employees):			
Small-sized	0.636	(0.481)	720
Medium-sized	0.315	(0.465)	720
Large-sized	0.049	(0.215)	720
# of employees (log)	2.166	(0.880)	720
Ownership	0.315	(0.465)	720
Operating 7 days per week	0.275	(0.447)	720
Service sector	0.492	(0.500)	720
Building characteristics			
Attached building	0.936	(0.245)	720
Insulation	0.107	(0.309)	720
Renovations since 2000	0.121	(0.326)	720
Space primarily for offices	0.212	(0.409)	720
Equipment stock			
A/C	0.356	(0.479)	720
Office equipment	0.876	(0.329)	720
Server	0.365	(0.482)	720
Other appliances	0.618	(0.486)	720
Commercial/Walk-in refrigerators	0.247	(0.432)	720
Water pump	0.525	(0.500)	720
Electric generator	0.039	(0.193)	720
Voltage regulator/stabilizer	0.385	(0.487)	720
Other relevant equipment	0.150	(0.357)	720
Consumption variability			
Coeff. of variation (kWh)	0.211	(0.216)	720
Behavioral			
Awareness of expenditure	0.588	(0.493)	720
Power saving habits	0.854	(0.354)	718
Intend to install solar panels	0.170	(0.376)	719

The table reports descriptive statistics of the main variables. Except for the number of employees, all variables are binary. Source: ENCENRE-2019.

We also considered equipment such as electric generators and voltage regulators or stabilizers, expecting these to influence tariff choices due to their impact on electricity consumption. Although few businesses have a generator (3.9%), a larger share has a regulator or stabilizer (38.5%). To capture variability in business electricity usage, we calculated the coefficient of variation of electricity consumption (in kWh).

Finally, we included three additional behavioral variables: awareness of utility bill expenditures (nearly 60% reporting awareness), engagement in power-saving habits like turning off lights and appliances (85.4% reporting this habit), and intentions to install solar panels within the next 12 months (with only 17% expressing such intentions).[15] These variables reflect attitudes toward energy management and can significantly affect selecting electrical tariffs.

4.2 Electricity bills data

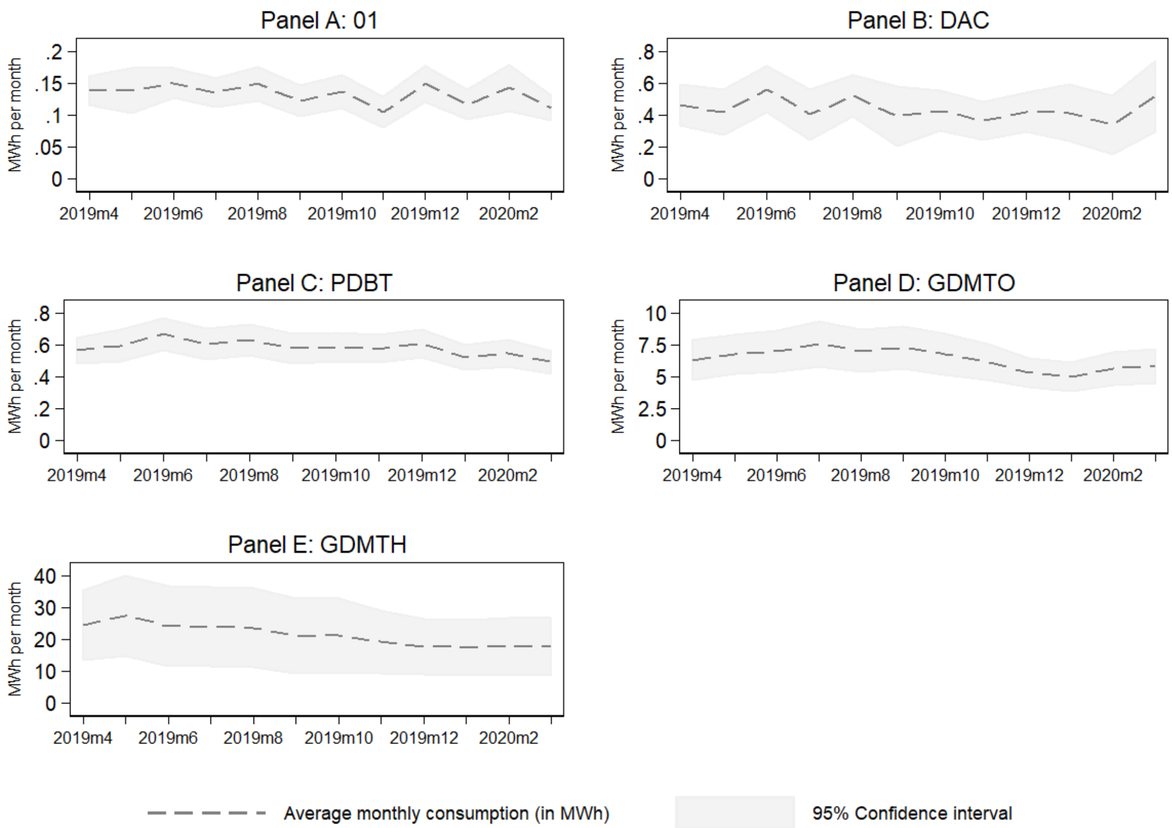
For most firms in the ENCENRE-2019 sample, we have monthly or bimonthly billing data, depending on the tariff category contracted by each firm.[16] We standardized the bimonthly data into monthly figures. This dataset covers the period from April 2019 to March 2020, preceding the impact of the COVID-19 pandemic on economic activity in Mexico.

Figure 2 illustrates the monthly average electricity consumption (in MWh) by tariff category over the entire period, accompanied by a 95% confidence interval. Businesses in the low-voltage tier generally exhibit lower energy consumption. Specifically, those under the residential tariff 01 (Panel A) show the smallest consumption, averaging 133 kWh/month. Panel B depicts businesses under the high-demand residential rate DAC, with higher consumption levels averaging around 436 kWh/month. These businesses consume electricity at levels comparable to those under the PDBT business rate, which averages 584 kWh/month. This suggests that DAC businesses and those operating under the PDBT rate may have similar energy consumption patterns or operational requirements. Panels D and E indicate significantly higher average monthly consumption among businesses in the medium-voltage tier, particularly for those under the peak-load pricing tariff GDMTH. Businesses under GDMTO and GDMTH have average consumption levels of 6.4 MWh/month and 21.3 MWh/month, respectively, highlighting that those under the peak-load pricing tariff GDMTH consume approximately three times more on average.

[15]The survey question not only asks if the respondent was aware of the expenditure but also inquired about the amount in the utility bill. To construct this variable, we cross-checked the reported amount with the utility bills to ensure that those who reported awareness were within two standard deviations of the average utility bill consumption.

[16]Low-voltage tariffs, including residential tariffs (01 and DAC) and the business tariff PDBT, are billed bimonthly, whereas high-demand medium-voltage business tariffs (GDMTO and GDMTH) are billed monthly.

Figure 2: Average monthly consumption by tariff category



This figure shows the average monthly consumption in MWh for each tariff category. The shaded area represents the 95% confidence interval. Source: own elaboration using CFE billing data.

5 Empirical Results

This section presents the results regarding the factors associated with the selection of suboptimal tariffs, encompassing both suboptimal PDBT and suboptimal GDMTO/H choices together. We also analyze these two tariff mistakes separately, as they may differ in nature. Additionally, we present results related to the selection of the residential (illegal) rate.

5.1 Suboptimal Tariff Choices

Table 4 presents our main results regarding firm and building characteristics, equipment inventory, electricity consumption variability, and behavioral factors associated with suboptimal tariff choices. Columns (1) to (4) display coefficient estimates based on a logit model, with corresponding standard errors in parentheses. Column (1) contains our basic specification, while column (2) represents our most comprehensive specification. In column (3), we restrict the sample to businesses with a PDBT tariff, focusing on those that have made suboptimal PDBT choices and would benefit from switching to a GDMTO (high demand at medium voltage) tariff. Column (4) provides estimates for businesses making suboptimal GDMTO/H choices. Due to sample limitations, we simplified the specification by removing variables that predict failure perfectly.[17] In Appendix B, we report the corresponding OLS estimates.

In column (1), which contains our basic specification (Model 1), we begin our analysis by examining how firm characteristics relate to the likelihood of a business having a suboptimal tariff. These characteristics include the (log) number of employees, ownership of the building, operating seven days per week, and operating in the service sector (compared to the trade sector). Among these factors, only ownership and operating seven days per week significantly influence the likelihood of having a suboptimal tariff. Whether the company owns the building has a negative impact on the likelihood, suggesting that non-owners may face higher costs or challenges in adjusting tariffs. On the contrary, whether the business operates seven days per week positively affects the likelihood of having a suboptimal tariff, likely due to increased electrical equipment usage. Building characteristics, such as whether the building is attached or has undergone major renovations since 2000, also exhibit significant and positive relationships with having a suboptimal tariff. However, their significance diminishes in the more comprehensive model in column (2). Furthermore, the presence of air conditioning and specialized equipment like servers or commercial/walk-in refrigerators significantly contributes to businesses having a suboptimal tariff. This highlights the role of equipment that drives high electricity consumption in leading firms towards having a suboptimal tariff.

In column (2), we expand our basic specification by breaking down the business size and the service sector, and by incorporating behavioral variables. A notable finding is the heterogeneity among business sizes. Compared to small-sized businesses (omitted category), medium-sized businesses are more likely to operate with a suboptimal tariff, whereas larger-sized businesses are less likely to do so. This heterogeneity explains why the (log) number of employees was not significant in the previous specification (column 1). Ownership of premises and operating seven days per week remain significant. Operating in the service sector continues to show a negative, albeit statistically insignificant, relationship with having a suboptimal tariff, even when considering the breakdown into different sectors. The only sectors showing a positive coefficient are health care and social assistance, but they

[17] The sample includes 98 businesses with a GDMTO/H tariff, of which only 13 made a suboptimal choice.

also lack statistical significance. The presence of air conditioning and specialized equipment also remains significant. Interestingly, awareness of expenditure shows a positive and significant relationship with having a suboptimal tariff. This means that firms with greater awareness of their electricity costs are likelier to operate with suboptimal tariffs. However, this relationship may work in reverse; discovering high costs may prompt firms to become more aware of their expenditures. In contrast, engaging in power-saving habits like turning off lights or appliances when not in use is significant and negatively related to the likelihood of having a suboptimal tariff. This suggests that these businesses are more conscientious about electricity consumption and strive to operate more efficiently. Finally, we find no significant relationship between the intention to install solar panels and the likelihood of using a suboptimal tariff.

As mentioned earlier, 77.5% of the businesses in the sample use a PDBT tariff, with 26.9% (150 out of 558) of them having it as a suboptimal choice. In column (3), we narrow the focus to these businesses to examine the factors influencing their likelihood of having a suboptimal tariff –that is, where a higher demand at a medium voltage tariff would be more optimal. In other words, these businesses likely consume more electricity than anticipated, leading to higher electricity costs. Our results indicate that firm characteristics remain significant and have substantial effects. Business size, ownership of premises, and operating seven days per week show significant coefficients with stronger effects. The significance of business size disappears for larger-sized businesses, as expected, because those under the GDMTO/H tariffs–typically larger businesses–are excluded from this restricted sample. Similar to our previous findings, operating in the service sector generally shows statistically insignificant coefficients, except for the real estate and rental and leasing sectors. Furthermore, having air conditioning and specialized equipment continue to have positive and significant roles, alongside other relevant equipment such as air extractors. This indicates that high-demand electrical equipment likely contributes to having a suboptimal tariff among businesses under the PDBT scheme. Surprisingly, the coefficient of variation, which measures volatility in electricity consumption, is negative and significant. This means that businesses with less volatile consumption patterns tend to have suboptimal tariffs. One reason could be that firms with more volatile consumption frequently reassess their consumption needs and tariff options. Finally, awareness of expenditure remains significant, while the significance of power-saving habits diminishes among PDBT tariff businesses.

Table 4: Estimation Results: Factors Impacting Suboptimal Tariff Selection

	(1)		(2)		(3)		(4)	
	Model 1		Model 2		Model 2: PDBT		Model 3: GDMTO/H	
Aguascalientes municipality	-0.150	(0.455)	-0.113	(0.460)	0.355	(0.589)	-7.654***	(2.445)
# of employees (log)	0.001	(0.140)					-1.871***	(0.480)
Medium-sized enterprise			0.490*	(0.254)	1.063***	(0.303)		
Large-sized enterprise			-2.262***	(0.855)	-0.390	(1.034)		
Ownership	-0.962***	(0.250)	-0.912***	(0.257)	-1.166***	(0.327)	-2.004	(1.739)
Operating 7 days per week	0.829***	(0.250)	0.801***	(0.290)	1.244***	(0.362)	-1.430	(0.918)
Service sector	-0.166	(0.216)					-0.998	(1.014)
Information			-0.968	(1.322)	-1.007	(1.368)		
Finance & Insurance			-0.607	(0.567)	-0.641	(0.629)		
Real Estate & Rental & Leasing			-0.726	(0.631)	-1.324	(0.867)		
Prof., Scientific, & Tech. Services			-0.171	(0.350)	-0.238	(0.390)		
Admin. & Supp. & WM & R. Serv.			-0.521	(0.568)	-0.588	(0.746)		
Educational Services			-0.030	(0.783)	-0.408	(0.836)		
Health Care & Social Assistance			0.064	(0.524)	0.128	(0.650)		
Accommodation & Food Services			-0.108	(0.372)	-0.599	(0.437)		
Attached building	1.167*	(0.599)	0.779	(0.596)	-0.023	(0.675)		
Insulation	-0.013	(0.333)	-0.051	(0.352)	0.414	(0.400)	1.789	(1.393)
Renovations since 2000	0.500*	(0.299)	0.420	(0.307)	0.335	(0.406)	-2.762*	(1.451)
Space primarily for offices	-0.249	(0.292)	-0.253	(0.321)	-0.673*	(0.384)	3.496	(2.664)
A/C	0.718***	(0.238)	0.767***	(0.264)	1.512***	(0.344)	-6.677***	(1.953)
Office equipment	0.333	(0.377)	0.312	(0.398)	0.209	(0.449)		
Server	0.514**	(0.237)	0.579**	(0.249)	0.867***	(0.289)	-2.266	(1.562)
Other appliances	0.087	(0.223)	0.034	(0.232)	-0.034	(0.280)	1.885	(1.387)
Commercial/Walk-in fridge	0.888***	(0.266)	0.906***	(0.322)	1.969***	(0.393)	-3.011*	(1.542)
Water pump	0.209	(0.228)	0.217	(0.236)	0.276	(0.272)	-0.486	(1.673)
Electric generator	0.573	(0.475)	0.855*	(0.510)	0.999	(0.825)	11.123***	(3.475)
Voltage regulator/stabilizer	0.237	(0.208)	0.220	(0.221)	0.324	(0.261)	-1.120	(1.610)
Other relevant equipment	0.312	(0.286)	0.315	(0.301)	0.729**	(0.369)	3.889***	(1.255)
Coeff. of variation (kWh)	0.104	(0.429)	-0.109	(0.464)	-1.248*	(0.656)	18.674***	(5.217)
Awareness of expenditure			0.457**	(0.218)	0.789***	(0.268)	-0.311	(1.257)
Power saving habits			-0.483*	(0.286)	-0.353	(0.386)	-7.164***	(2.511)
Intend to install solar panels			-0.197	(0.291)	0.023	(0.333)	0.289	(1.312)
Constant	-3.496***	(0.916)	-3.007***	(0.863)	-3.531***	(1.033)	14.223***	(5.061)
Observations	656		653		556		97	
% Correctly classified	75.3		77.2		82.2		92.8	

The table reports coefficient estimates of the determinants of suboptimal tariff selection. Robust standard errors are in parentheses. Except for the log number of employees, all variables are binary. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Source: ENCENRE-2019.

In column (4), we replicate the analysis, narrowing our focus to businesses using a GDMTO/H tariff. The suboptimal selection of tariffs by these businesses is likely due to them consuming less electricity than expected while paying higher rates, resulting in increased electricity costs. Our sample includes 98 businesses with a GDMTO/H tariff, of which only 13 made a suboptimal choice. Due to this reduced sample, we removed several variables and estimated a version similar to our basic specification (Model 1). The results indicate that businesses with more employees are less likely to have a suboptimal tariff. Interestingly, the presence of air conditioning or walk-in refrigerators is negatively related to having a suboptimal tariff, contrasting with the findings from PDBT tariff businesses. This suggests distinct electricity needs and operational practices between businesses using PDBT versus GDMTO/H tariffs. However, other relevant equipment shows a positive relationship with a suboptimal tariff. Unlike businesses under the PDBT tariff, the coefficient of variation is significant and positive in this context. This aligns with the notion that volatile consumption among these businesses is linked to suboptimal choices. Lastly, the significance of awareness of expenditure diminishes, while the significance of power-saving habits remains within this group of businesses. This suggests that while these businesses are conscious of their electricity costs, effective energy-saving practices are still relevant in managing their electricity expenses.

Overall, our analysis reveals that firm characteristics such as business size, operational intensity, and equipment type significantly influence the likelihood of businesses adopting suboptimal electricity tariffs. Spcifically, medium-sized businesses and those with high operational intensities tend to select suboptimal tariffs, likely driven by unforeseen high electricity demands. Equipment like air conditioning and specialized appliances plays a crucial role, while consumption volatility and cost awareness further shape tariff decisions.

5.2 Residential (Illegal) Tariff Choices

Table 5 presents our main results regarding factors associated with the selection of a residential (illegal) tariff. Columns (1) to (3) display coefficient estimates based on a logit model, with corresponding standard errors in parentheses. Column (1) contains our basic specification, while column (2) includes a breakdown by service sector and incorporates behavioral variables. Column (3) represents our most comprehensive specification.

In column (1), we observe that a higher number of employees decreases the likelihood that a business will operate with a residential tariff. Similarly, businesses in the service sector are more inclined to adopt this tariff. Firm characteristics such as ownership of the premises or operating seven days per week do not significantly explain the use of a residential tariff. Similarly, building characteristics such as whether the building is attached, insulated, or has undergone renovations are not significant factors. In contrast, the presence of air conditioning, a commercial or walk-in refrigerator, and a voltage regulator or stabilizer have a negative effect, indicating that businesses with such equipment are less likely to have a residential tariff. Air conditioning and walk-in refrigerators are significant drivers of electricity consumption. Due to the continuous operation of this equipment, businesses typically have higher electricity needs, making them less likely to choose residential tariffs. Similarly, the presence of a voltage regulator or stabilizer may indicate a better understanding of electricity consumption and needs, potentially discouraging the adoption of a residential tariff. On the other hand, having a water pump or an electric generator is associated with the use of a residential tariff. The presence of a water pump tends to be a common feature among households in the area, with 37.2% of housing stock having one, while an electric generator might indicate that these businesses are aware of their electricity needs and thus prefer to keep the subsidized tariff.[18] Unfortunately, we do not know the capacity or purpose of the generator, whether it is for temporary power needs, emergencies, or backups, which could tell us more about the reasons behind this effect.

In column (2), we break down the service sector and include our behavioral variables. Interestingly, we find that, except for the accommodation and food service sector, all other included service sectors are positively associated with using a residential tariff, though not all of them are statistically significant. However, it's noteworthy that the information, professional, scientific, and technical services, as well as administrative and support and waste management and remediation services sectors, have significant effects. A common feature among businesses in these sectors is that they typically operate in office spaces, which often resemble residential buildings. In fact, when we include whether most of the space is used for offices in column (3), the significance across all service sectors disappears. This suggests that service-oriented businesses operating in office spaces are more likely to use a residential tariff. We do not find any significant effects from our variables capturing variation in consumption, awareness of electricity expenditure, engagement in power-saving habits, or intentions to install a solar panel over the next year.

[18] Source: National Survey of Household Income and Expenditure (ENIGH). 2022.

Table 5: Estimation Results: Factors Impacting Residential (Illegal) Tariff Selection

	(1)		(2)		(3)	
	Model 1		Model 2		Model 3	
Aguascalientes municipality	-0.187	(0.723)	-0.086	(0.721)	-0.087	(0.751)
# of employees (log)	-0.534**	(0.225)	-0.552**	(0.220)	-0.593***	(0.227)
Ownership	-0.218	(0.343)	-0.246	(0.360)	-0.214	(0.361)
Operating 7 days per week	0.048	(0.412)	0.252	(0.431)	0.373	(0.444)
Service sector	0.833***	(0.294)				
Information			1.777**	(0.895)	1.315	(0.872)
Finance & Insurance			0.561	(1.188)	0.297	(1.149)
Real Estate & Rental & Leasing			0.596	(0.655)	0.049	(0.735)
Prof., Scientific, & Tech. Services			1.162***	(0.421)	0.634	(0.526)
Admin. & Supp. & WM & R. Serv.			1.169**	(0.526)	0.765	(0.580)
Educational Services			0.843	(1.187)	0.962	(1.175)
Health Care & Social Assistance			1.061	(0.665)	1.048	(0.638)
Accommodation & Food Services			-0.144	(0.573)	-0.210	(0.588)
Attached building	0.514	(0.753)	0.437	(0.749)	0.413	(0.808)
Insulation	-0.282	(0.549)	-0.284	(0.551)	-0.363	(0.555)
Renovations since 2000	0.442	(0.496)	0.559	(0.521)	0.549	(0.531)
Space primarily for offices					0.994**	(0.421)
A/C	-1.527***	(0.463)	-1.583***	(0.506)	-1.600***	(0.506)
Office equipment	0.093	(0.448)	0.005	(0.463)	-0.146	(0.461)
Server	-0.142	(0.340)	-0.193	(0.349)	-0.112	(0.369)
Other appliances	0.002	(0.295)	0.048	(0.301)	0.044	(0.306)
Commercial/Walk-in fridge	-1.142**	(0.457)	-0.616	(0.477)	-0.547	(0.489)
Water pump	0.740**	(0.295)	0.803***	(0.297)	0.872***	(0.303)
Electric generator	1.959***	(0.760)	1.812**	(0.786)	1.908**	(0.830)
Voltage regulator/stabilizer	-0.785**	(0.338)	-0.788**	(0.345)	-0.785**	(0.355)
Other relevant equipment	-0.218	(0.704)	-0.165	(0.700)	-0.109	(0.696)
Coeff. of variation (kWh)	0.262	(0.564)	0.288	(0.558)	0.257	(0.566)
Awareness of expenditure			-0.338	(0.279)	-0.365	(0.286)
Power saving habits			0.167	(0.424)	0.201	(0.418)
Intend to install solar panels			-0.156	(0.418)	-0.111	(0.437)
Constant	-1.703	(1.210)	-1.718	(1.330)	-1.720	(1.426)
Observations	622		620		620	
% Correctly classified	89.7		89.7		89.7	

The table reports coefficient estimates of the determinants of residential (illegal) tariff selection. Robust standard errors are in parentheses. Except for the log number of employees, all variables are binary. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Source: ENCENRE-2019.

Overall, our results clearly identify the types of businesses that typically use a residential tariff. These businesses are generally smaller in size and primarily operate in the service sectors. Specifically, businesses in information, professional, scientific, and technical services, as well as administrative and support and waste management and remediation services, are more likely to use a residential tariff. Moreover, businesses with residential tariffs often occupy spaces primarily used as offices. Since these businesses could easily operate in buildings that resemble residential structures, such as houses or apartments, and their electricity consumption patterns may mirror those of residential households, they are likely to choose a residential tariff despite it being illegal for businesses.

6 Hidden Cost of Tariff Misclassification

The results from the previous section are both relevant and significant. However, it is important to put them into perspective to fully understand their impact on firms' electricity expenditures and budgets, utility profitability, and, more fundamentally, to uncover potential improvements in public policy.

In this section, we first provide aggregate calculations for the Aguascalientes Metro Area, combining the results from our representative sample and the distribution of firms according to the National Statistical Directory of Economic Units (DENUE), which serves as the sampling frame in our study.[19] Second, we present back-of-the-envelope calculations extrapolating our results to the national level. As shown in Table 10 in Appendix B, Aguascalientes has a similar distribution of businesses by size as the country as a whole, with the vast majority (85.1%) consisting of fewer than five employees. In that sense, the extrapolation exercise presented in this section is very informative, although it should be approached with some caution.

We begin by examining the companies with PDBT and GDMTO tariffs that made suboptimal choices. Table 6 presents the average excess electricity spending per firm, categorized by stratum of occupied personnel, as recorded in the DENUE. For this calculation, we also included establishments with 0 to 5 employees from the random sample used in Hancevic, Sandoval, and Bejarano (2024).[20]

For the suboptimal businesses, the excess electricity spending is $1,622 MXP on average per billing period, representing approximately 15% of the electricity bill paid. Although none of the surveys used in the analysis provide information on the total expenditures of the firms, we rely on Economic Census data, which indicate that the electricity expenditure

[19]In the National Statistical Directory of Economic Units (DENUE), data on the identification, location, economic activity, and size of active businesses in the national territory are offered, with updates primarily in the segment of large establishments. All the information and data regarding the DENUE is available at: https://en.www.inegi.org.mx/app/mapa/denue/default.aspx

[20]This study uses as well the DENUEE as their sampling frame. It focuses on the same geographical area (Aguascalientes Metropolitan Area), and also has establishments' billing data directly obtained from the national utility CFE. This combined information allows us to compute the suboptimal spending in a similar fashion to what was done with our sample in this paper (see Appendix A for more details). We do not use this data in the analysis of our previous section because we do not have the same business characteristics.

share of the total expenditure for the strata considered here is between 0.5% and 3% on average.

Table 6: Estimated Excess Electricity Bill Spending Due to Suboptimal Tariff Selection in the Metropolitan Area of Aguascalientes by Occupied Personnel Stratum.

		Stratum of occupied personnel				
		0 to 5(*)	6 to 10	11 to 30	31 to 100	Total
Suboptimal:						
Yes	count	1,250	649	711	214	2,824
	excess spending	$820	$2,030	$2,236	$2,928	$1,622
		($995)	($2,830)	($2,514)	($2,712)	($2,238)
No	count	37,901	2,963	1,671	439	42,974
Total		39,151	3,612	2,382	653	45,798

The table reports the average excess electricity spending by stratum of occupied personnel according to the classification of the Mexican National Institute of Statistics and Geography (INEGI). Excess spending is measured in MXP per billing period. Source: own calculations using the National Statistical Directory of Economic Units (DENUE) and ENCENRE-2019.
(*) Calculations for the stratum 0-5 employees were made using data from Hancevic et al. (2024) who also uses the DENUEE as the sampling frame to collect firm level data in the Aguascalientes Metropolitan Area.

Given the magnitude of the findings, the financial impacts of selecting a suboptimal electricity tariff cannot be ignored. This choice results in higher electricity costs, which directly affect a firm's overall expenditures and profitability. By correcting this suboptimal behavior, companies can significantly reduce their energy expenses. This improves their financial health and enhances their competitiveness in the market. Additionally, adopting more efficient tariff choices can contribute to better industry resource management and sustainability practices. Thus, addressing and rectifying suboptimal tariff decisions extends beyond mere cost savings, influencing broader economic and environmental outcomes.

When aggregating the results for the Metropolitan Area of Aguascalientes, the excess spending totals 27.4 million Mexican Pesos per year. Extending this to the national level, assuming the same average excess spending and considering that there are more than 4.7 million firms in these strata of occupied personnel, the figure expands to 3 billion MXP per year.

Now, we need to address the second issue analyzed in this paper: companies using residential tariffs. This involves quantifying the subsidies they receive from the government, which are unfair, incorrect, and illegal. Table 7 presents the average subsidy received by firms under the 01 tariff and, conversely, the excess spending of firms with DAC tariff. The reference category for this calculation is the business PDBT tariff, which is used as the counterfactual situation.

Table 7: Estimated Illegal Subsidies in the Metropolitan Area of Aguascalientes by Occupied Personnel Stratum.

Category	Stratum of occupied personnel 0 to 5(*)	6 to 10	11 to 30	31 to 100	Total
01 Tariff					
count	14,213	320	34	45	14,612
illegal subsidy	$660	$872	$662	$872	$665
	($604)	($277)	($337)	($310)	($599)
DAC Tariff					
count	66	104	34	11	215
excess spending	$837	$780	$477	$950	$759
	($1,328)	($1,236)	($1,394)	($1,055)	($1,287)
Non-Residential contract					
count	24,872	3,188	2,314	597	30,971

The table reports the average subsidy received by firms with 01 residential tariff and average excess electricity spending of firms with DAC tariff by stratum of occupied personnel. Subsidy and excess spending are measured in Mexican Pesos per billing period. Source: own calculations using the National Statistical Directory of Economic Units (DENUE) and ENCENRE-2019.
(*) Calculations for the stratum 0-5 employees were made using data from Hancevic et al. (2024) who also uses the DENUEE as the sampling frame to collect firm level data in the Aguascalientes Metropolitan Area.

In Aguascalientes, about 31% of commercial and service firms with 0 to 100 employees contract the residential tariff. For this calculation, we again included establishments with 0 to 5 employees from the sample used in Hancevic et al. (2024). Firms under the 01 tariff are illegally receiving the residential electricity subsidy, with each firm in this category receiving an average of $665 per billing period. Additionally, firms under the DAC tariff are paying $759 in excess. Considering the number of firms in each tariff category, the total annual subsidy amounts to 58.3 million MXP, while the excess spending is 1 million MXP per year. Consequently, the net subsidy is above 57 million MXP per year. Extrapolating these figures to the national level translates to a net subsidy of slightly more than 6.4 billion Mexican Pesos per year. That amount represents approximately 8% of the total budget approved to subsidize electricity rates for all types of uses in 2023.

When SMEs contract residential electricity tariffs and receive subsidies intended for households, they misallocate resources, increasing public expenditures and diverting funds from those in need. This practice creates market distortions, reducing incentives for energy efficiency, and leads to unfair competition as subsidized businesses gain an advantage over those paying commercial rates. The resulting higher electricity consumption can exacerbate environmental issues and carbon emissions. Ultimately, this undermines the effectiveness of policies aimed at supporting vulnerable households by misdirecting the benefits of subsidies. We recognize that the government may aim to support specific micro, small, and medium-sized enterprises through subsidies as a policy objective. However, the most effective approach is to provide transparent aid through a special rate tailored for the targeted businesses, rather than subsidizing them through the residential rate.

7 Concluding comments

This study investigates the misclassification of energy tariffs among small and medium-sized enterprises (SMEs) in Aguascalientes, Mexico. The hidden costs of tariff misclassification have two aspects. First, a substantial group of firms has contracted the residential electricity rate. The improper subsidy received by these firms at the national level is estimated to be over 6.4 billion Mexican Pesos per year, representing approximately 8% of the total budget approved to subsidize electricity rates for all types of uses in 2023. Second, for another group of companies, their choice of tariff results in higher electricity costs, directly affecting their overall expenditures and profitability. At the national level, this amounts to 3 billion MXP per year in higher costs.

Our analysis focuses on the determinants of tariff selection, exploring both the theoretical and empirical aspects of tariff self-selection. Our findings reveal significant insights into the factors influencing SMEs' choices of electricity tariffs and the economic implications of these choices. Specifically, our results show that firm characteristics like size, operating schedule, sector type, and equipment significantly influence the choice of electricity tariffs. Specifically, medium-sized businesses operating seven days a week and with air conditioning and specialized equipment tend to opt for suboptimal tariffs. This suggests that continuous operation throughout the week and using high-demand electrical equipment contribute to selecting less efficient tariffs. In contrast, businesses using residential tariffs are predominantly in service sectors, often based in office spaces. These businesses typically operate in buildings resembling residential structures like houses or apartments, and their electricity usage patterns may resemble those of households. This similarity likely explains their preference for residential tariffs despite being against business regulations.

Additionally, in a somewhat speculative manner, one of the primary factors contributing to tariff misclassification is the lack of information or understanding about the available tariff options. SMEs often lack the necessary information or the ability to accurately predict their future electricity consumption, leading to suboptimal tariff choices. The complexity of the tariff structures themselves can lead to misclassification. The presence of multiple tariff categories, each with its own pricing scheme and conditions, creates a challenging environment for SMEs to navigate. This complexity can result in firms inadvertently selecting tariffs that do not align with their consumption patterns.

Behavioral factors, such as rational inattention, bounded rationality, and norms-adopting behavior, also play a crucial role in tariff misclassification. SMEs may not invest the time and effort required to thoroughly analyze their tariff options, leading to decisions that are not economically optimal.

Incorporating insights from behavioral economics into the design of tariff selection processes can help address the cognitive and behavioral factors contributing to misclassification. Simplified decision-making tools and nudges can guide SMEs towards more optimal tariff choices.

The economic implications of tariff misclassification are significant, affecting SMEs and utility providers. Misclassification can lead to higher electricity costs for SMEs. Firms that select suboptimal tariffs may pay more than necessary for their electricity consumption, reducing their profitability and competitiveness. Tariff misclassification can also impact utility providers' revenue streams. Misclassified tariffs may result in lower revenues from SMEs that select lower-cost residential tariffs instead of higher-cost business tariffs. Conversely, firms with inappropriately high tariffs may lead to inefficient revenue collection and potential loss of consumer trust.

The findings highlight the need for policy and regulatory interventions to address tariff misclassification. Simplifying tariff structures, enhancing information dissemination, and implementing better monitoring and enforcement mechanisms are essential to ensure that SMEs select the most appropriate tariffs for their needs.

Several policy recommendations are proposed to mitigate the issue of tariff misclassification. First, simplifying the tariff structures can make it easier for SMEs to understand and select the most appropriate tariffs. This could involve reducing the number of tariff categories and providing clearer guidelines on each category's conditions and pricing schemes. Second, providing SMEs better access to information about the available tariff options and their implications can help firms make more informed decisions. This could involve targeted outreach programs, workshops, and online resources tailored to the needs of SMEs. Third, strengthening the monitoring and enforcement mechanisms can reduce the incidence of tariff misclassification. Regular audits and checks can ensure that SMEs are on the correct tariffs and that any discrepancies are promptly addressed.

The study opens several avenues for future research. Conducting longitudinal studies to track the tariff selection behavior of SMEs over time can provide deeper insights into the dynamics of tariff misclassification and the effectiveness of policy interventions. Comparing the tariff selection behaviors and outcomes across different regions and countries can help identify best practices and common challenges in addressing tariff misclassification. Exploring the impact of technological advancements, such as smart meters and data analytics, on tariff selection and energy consumption patterns can offer valuable insights into how technology can be leveraged to reduce misclassification.

In conclusion, the misclassification of energy tariffs among SMEs has significant economic implications for both firms and utility providers. Addressing this issue requires a multifaceted approach that simplifies tariff structures, enhances information dissemination, improves monitoring and enforcement, and incorporates behavioral insights into policy design. By implementing these recommendations, policymakers can help ensure that SMEs select the most appropriate tariffs, leading to more efficient and cost-effective energy consumption.

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A Optimal choice calculations

To compare the optimality of contracting PDBT or GDMTO tariffs, we need first to compute the annualized installation cost of transformers. We assume that the transformer is purchased with an 18-month credit considering a 10% annual interest rate. On average, the typical lifespan of transformers is between 20 and 35 years, so we assume an intermediate value.

For users whose bills did not include information about the connected or contracted load, we imputed it using the coefficients of an ad-hoc quadratic regression. The installation and maintenance cost of transformers (including materials and labor) is assumed to be 4,500 MXP.

The discount rate is $r = (1 + 0.10)^{1/12} - 1$ and the monthly discount factor is therefore $D = \frac{(1+r)^{18}-1}{r(1+r)^{17}}$. The resulting switching cost, SC, is

$$SC = \begin{cases} [(362L - 0.38L^2) + 4500] \times D^{-1} & \text{for L} \leq 10 \\ [(362L - 0.38L^2) \times 1.30 + 4500] \times D^{-1} & \text{for L} > 10 \end{cases}$$

The switching cost is then added to the PDBT tariff for the counterfactual GDMTO tariff. Conversely, the switching cost is subtracted from the GDMTO tariff when computing the counterfactual PDBT tariff.

The computation of expenditure under GDMTO requires using the maximum demand (MD) during each billing period. To compute the MD, we rely on an approximation of the formula used by the utility CFE

$$MD = \frac{\bar{e}}{24 \times 30 \times 1.85}$$

where $\bar{e}$ is the average consumption of the firm, the denominator includes 24 hours of the day and 30 days of the month, and the scale factor is 1.85. The MD is then multiplied by the capacity and distribution charges included in the GDMTO tariff formula.

Using the different tariff schedules, we construct counterfactual expenditures under each tariff and select the lowest one. The dependent variable in the estimation results presented in Table 4 takes on the value 1 if the firm chooses the wrong tariff and 0 otherwise.

For the estimates in Table 5, the consideration is simpler. The dependent variable equals one if the firm has residential tariffs (01 or DAC) and 0 otherwise.

B Supplemental Tables and Figures

Table 8: OLS Results: Factors Impacting Suboptimal Tariff Selection

	(1)		(2)		(3)	
	OLS Model 2		OLS M2: PDBT		OLS M3: GDMTO/H	
Aguascalientes municipality	0.000	(0.081)	0.065	(0.092)	-0.239*	(0.133)
Medium-sized enterprise	0.093**	(0.045)	0.159***	(0.048)		
Large-sized enterprise	-0.284***	(0.074)	-0.020	(0.159)		
Ownership	-0.127***	(0.034)	-0.124***	(0.035)	-0.013	(0.067)
Operating 7 days per week	0.134***	(0.047)	0.185***	(0.050)	-0.011	(0.054)
Information	-0.116	(0.150)	-0.066	(0.171)		
Finance & Insurance	-0.116	(0.088)	-0.105	(0.097)		
Real Estate & Rental & Leasing	-0.055	(0.060)	-0.071	(0.068)		
Prof., Scientific, & Tech. Services	-0.024	(0.051)	-0.027	(0.050)		
Admin. & Supp. & WM & R. Serv.	-0.059	(0.072)	-0.045	(0.071)		
Educational Services	-0.009	(0.163)	-0.054	(0.157)		
Health Care & Social Assistance	-0.012	(0.073)	-0.005	(0.076)		
Accommodation & Food Services	0.002	(0.065)	-0.059	(0.068)		
Attached building	0.088	(0.069)	-0.023	(0.083)		
Insulation	-0.015	(0.059)	0.058	(0.066)	-0.016	(0.056)
Renovations since 2000	0.068	(0.056)	0.054	(0.064)	-0.060	(0.081)
Space primarily for offices	-0.027	(0.043)	-0.063	(0.043)	0.014	(0.107)
A/C	0.119***	(0.042)	0.182***	(0.045)	-0.163*	(0.098)
Office equipment	0.043	(0.049)	0.042	(0.049)		
Server	0.086**	(0.039)	0.103***	(0.040)	-0.000	(0.077)
Other appliances	-0.003	(0.034)	-0.015	(0.034)	0.053	(0.073)
Commercial/Walk-in fridge	0.150***	(0.053)	0.285***	(0.059)	-0.156*	(0.078)
Water pump	0.031	(0.036)	0.043	(0.035)	-0.013	(0.084)
Electric generator	0.142	(0.094)	0.148	(0.124)	0.328**	(0.135)
Voltage regulator/stabilizer	0.035	(0.034)	0.052	(0.035)	0.025	(0.067)
Other relevant equipment	0.044	(0.055)	0.108*	(0.061)	0.094	(0.078)
Coeff. of variation (kWh)	-0.007	(0.065)	-0.111*	(0.063)	0.951***	(0.219)
Awareness of expenditure	0.071**	(0.031)	0.100***	(0.032)	-0.004	(0.067)
Power saving habits	-0.068	(0.047)	-0.040	(0.048)	-0.167	(0.112)
Intend to install solar panels	-0.031	(0.044)	-0.014	(0.045)	-0.040	(0.069)
# of employees (log)					-0.069*	(0.039)
Service sector					0.012	(0.066)
Constant	-0.003	(0.125)	-0.043	(0.141)	0.593**	(0.248)
Observations	653		556		97	
R^2	0.203		0.341		0.411	

The table reports coefficient estimates of the determinants of suboptimal tariff selection. Robust standard errors are in parentheses. Except for the log number of employees, all variables are binary. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Source: ENCENRE-2019.

Table 9: OLS Results: Factors Impacting Residential (Illegal) Tariff Selection

	(1)		(2)	
	OLS Model 2		OLS Model 3	
Aguascalientes municipality	-0.012	(0.065)	-0.015	(0.066)
# of employees (log)	-0.043**	(0.019)	-0.046**	(0.019)
Ownership	-0.017	(0.029)	-0.015	(0.029)
Operating 7 days per week	0.026	(0.033)	0.033	(0.033)
Information	0.215	(0.152)	0.158	(0.158)
Finance & Insurance	0.034	(0.057)	0.015	(0.055)
Real Estate & Rental & Leasing	0.053	(0.056)	0.010	(0.059)
Prof., Scientific, & Tech. Services	0.099**	(0.043)	0.051	(0.049)
Admin. & Supp. & WM & R. Serv.	0.121*	(0.066)	0.084	(0.067)
Educational Services	0.082	(0.132)	0.081	(0.132)
Health Care & Social Assistance	0.091	(0.071)	0.091	(0.069)
Accommodation & Food Services	-0.015	(0.040)	-0.020	(0.040)
Attached building	0.029	(0.050)	0.036	(0.052)
Insulation	-0.017	(0.036)	-0.018	(0.036)
Renovations since 2000	0.049	(0.042)	0.047	(0.042)
Space primarily for offices			0.096**	(0.042)
A/C	-0.102***	(0.026)	-0.103***	(0.026)
Office equipment	0.004	(0.042)	-0.003	(0.041)
Server	-0.011	(0.027)	-0.009	(0.027)
Other appliances	0.002	(0.027)	0.002	(0.026)
Commercial/Walk-in fridge	-0.047	(0.032)	-0.038	(0.032)
Water pump	0.064***	(0.025)	0.069***	(0.025)
Electric generator	0.165	(0.104)	0.174	(0.107)
Voltage regulator/stabilizer	-0.050**	(0.024)	-0.047**	(0.023)
Other relevant equipment	0.001	(0.032)	0.001	(0.032)
Coeff. of variation (kWh)	0.025	(0.058)	0.030	(0.058)
Awareness of expenditure	-0.020	(0.024)	-0.022	(0.024)
Power saving habits	0.010	(0.034)	0.015	(0.033)
Intend to install solar panels	-0.024	(0.031)	-0.017	(0.031)
Constant	0.161	(0.106)	0.148	(0.106)
Observations	620		620	
R^2	0.083		0.094	

The table reports coefficient estimates of the determinants of residential (illegal) tariff selection. Robust standard errors are in parentheses. Except for the log number of employees, all variables are binary. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Source: ENCENRE-2019.

Table 10: Stratification of Business Establishments by Number of Employees

Number of	All country		Aguascalientes MA	
employees	Freq.	Percent	Freq.	Percent
0 - 5	4,187,047	88.1%	39,151	85.1%
6 - 10	294,086	6.2%	3,612	7.8%
11 - 30	195,437	4.1%	2,382	5.2%
31 a 50	36,523	0.8%	414	0.9%
51 - 100	21,544	0.5%	239	0.5%
101 - 250	12,703	0.3%	161	0.3%
251 or +	5,897	0.1%	55	0.1%
Total	4,753,237	100.0%	46,014	100.0%

Source: This table was reproduced from Hancevic and Sandoval (2023), who used data from the DENUE.