CENTRO DE INVESTIGACIÓN Y DOCENCIA ECONÓMICAS, A.C.

ELECTRICITY TARIFF RE-BALANCING: ECONOMIC EFFICIENCY, DISTRIBUTIONAL AND ENVIRONMENTAL GOALS WITHIN THE MEXICAN CONTEXT

TESINA

QUE PARA OBTENER EL GRADO DE

MAESTRO EN ECONOMÍA AMBIENTAL

PRESENTA

JUAN PABLO LONDOÑO AGUDELO

DIRECTOR DE LA TESINA: DR. PEDRO IGNACIO HANCEVIC

AGUASCALIENTES, MÉXICO JUNIO, 2019

Acknowledgments

Quiero agradecer a mi familia, especialmente a mis padres, Luz Ángela y Efraín, y a mi tía Diana, por todo lo que me han enseñado a lo largo de mi vida y el apoyo que me brindaron, desde la distancia, durante este proceso. A Luis y Carmina, quienes se convirtieron en mi familia en México. A mis amigos y compañeros, con quienes compartí una experiencia sin precedentes en mi vida. A mis maestros, de quienes obtuve conocimientos invaluables, en especial al Dr. Pedro Hancevic y al Dr. Hector Núñez, por su guía y apoyo durante mis estudios y el desarrollo de esta investigación. Finalmente, a mis mentores en Colombia, Johanna Vásquez y Jonathan Gómez, quienes me llenaron de herramientas y consejos para enfrentar este reto. A todos ustedes, mil gracias.

Abstract

The design of optimal pricing schedules for electricity has been an important target of utilities within the energy sector. For this, goals of economic efficiency, re-distribution of income and environmental externalities might be considered. However, commonly used electricity tariff schedules, such as the Increasing Block Tariff (IBT), set prices that differ significantly from marginal cost. This leads to inefficiencies and issues with the subsidies targeting mechanism. This research assesses the effect on consumer welfare within the Mexican context of a shift from its current pricing scheme, an IBT, to an economic efficient scenario in which environmental externalities are considered. Furthermore, a proxy mean-test program and a perfect targeting mechanism scenario to improve distributional outcomes are assessed. Results show that economic efficiency does represent an optimal situation for utilities, Under which full cost recovery is achieved. However, a significant economic burden is imposed to low-income households due to the 100% reduction in the subsidy. In contrast, is observed that a progressive decrease in the subsidy, along with the usage of mechanism to accurately assign the fixed cost charge, according to the income of households, may improve distributional outcomes using economic efficiency as a baseline scenario.

Key words: Electricity tariff, Increasing Block Tariff, Mexico, Economic efficiency, Redistribution of income, Environmental externalities.

Contents

1 Introduction **1**

2 Literature review **4**

3 Tariffs **9**

4 Mexican electricity tariffs **14**

5 Data **20**

6 Tariff re-balancing results **28**

6.1 Economic efficiency and externatlities 29

6.1.1 Inefficiency and Consumer Surplus 32

6.2 Re-distribution of income strategies 34

7 Conclusions **39**

Appendix A Proxy mean-test regression results **43**

Bibliography **50**

List of Figures

3.1 Increasing Block Tariff with two blocks 12

4.1 Regional Control Centers 19

5.1 Average hourly energy demand 21

5.2 Marginal prices by Regional Control Center 22

6.1 Variations in Consumer Surplus by expenditure decile under economic efficiency . 33

List of Tables

4.1 Residential tariffs groups and blocks in the Mexican IBT scheme 17

4.2 DAC rates for each Regional Control Center during summer 18

5.1 Energy consumption related variables description 23

5.2 Average energy consumption (kWh) per expenditure decile 24

5.3 Average energy expenditure in USD per expenditure decile 25

5.4 Energy Consumption (kWh) by tariff category for the ENIGH 2016 25

5.5 Households in each block by expenditure decile - Tariff categories 1, 1A and 1B . . 26

5.6 Households in each tier by expenditure decile - Tariff categories 1C to 1F 27

6.1 Energy subsidy by expenditure decile 30

6.2 Changes in energy consumption and energy expenditure by decile 31

6.3 Inefficiency from the IBT scheme by expenditure decile (USD) 32

6.4 Energy expenditure variations among the proposed strategies by expenditure decile 38

A.1 Mean-test index regression results 43

1 | Introduction

A challenging situation in most emerging countries is to fulfill multiple objectives with a reduced number of (imperfect) policy instruments and limited resources. Some of them related to the supply of public services which, due to the cost structure underneath (generally because of fixed cost) imply the presence of natural monopolies as a solution to *incomplete markets*. This market failure is the result of the lack of incentives of the private sector to participate and compete (Passey *et.al.* 2017). This is usually observed in the provision of water and electricity, where state companies must not only provide the actual service but also build the necessary infrastructure to accomplish it. The way to charge users for these services has been a leading issue when considering the interaction of targets that may be in conflict, such as economic efficiency, income distribution and equity.

Consequently, the design of optimal tariffs has been an important goal of public utilities in this sector and has been studied by different researchers for decades, *e.g.* Henson (1984) and Dutta and Mitra (2017). In the case of residential electricity, distributional goals have been the main priority over economic efficiency and environmental issues. The former entails an essential theoretical economic precept: the marginal price that a user pays for one extra unit of energy must be equal to the marginal cost of supplying it. Nonetheless, this is not followed in practice when other targets, such as more proper re-distribution of income, have a preponderant role, which in most emerging countries with high levels of income inequality, seems to be the current situation (Whittington, 1992). On the other hand, the latter refers to a tariff that covers the social cost linked to the polluters due to the energy provision, such as those from the energy generation process.

Among the different tariff schemes that exists, the Increasing Block Tariff is one of the most common applied around the world (Sun and Lin, 2013; Dutta and Mitra, 2017; Cardenas and Whittington, 2019). This scheme defines groups of energy users according to the quantity of electricity used during the billing period. The subsidy if there is any, is reduced as consumption increases; however, its design and implementation move away from the economic precept mentioned before. Thus economic efficiency is not achieved; therefore a tariff re-balancing which allows the Mexican electricity regulator to manage this will be proposed.

In addition, if economic efficiency were the main objective, when one accounts for negative externalities such as air pollution and the excessive water resource usage, the private marginal cost of energy is unambiguously below the social marginal cost of energy. So, a quantitative measure of costs related to those externalities should be obtained to get the true cost stemmed from electricity provision services which will allow to improve economic welfare. These growing environmental concerns are an important part of the current policy agenda in many developed and developing economies.

In Mexico, the focus has been put on the reduction of Greenhouse Gas (GHG) emissions, thus, objectives related to the increase of renewable energy technologies in the energy matrix and energy efficiency have been set as a priority. This, under the structural Energy Reform of 2013, the General Law on Climate Change and the Energy Transition Law, both issued in 2015 in the framework of the Sustainable Development Goals at the United Nations (UN) where Mexico was an active participant. However, the new government has interrupted some of the processes that were in progress, casting doubts about the continuity and future of related public policies.

In the case of Mexico, more than 40% of its population live under the official poverty line (CONEVAL, 2016). The main focus has been made on a distributional objective which looks, in

theory, to reduce the economic burden of the lower income population through a subsidy scheme; it is implemented by means of seven different residential tariff categories. Each of this categories is divided into blocks that differ within them in consumption ranges and prices. The Mexican government subsidizes approximately 60% of the electricity expenditure for more than 98% of residential users (Centro de Investigación para el Desarrollo, 2015). That happens in a context of a complex and an inefficient electricity tariff schedule that tend to give higher benefits to the middle- and high-income class of the population. Households afford increasing block marginal prices and are severely penalized when crossing an annual consumption threshold. In addition, the computation of the system costs does not include any measure of air pollution or water resource usage.

Thus, considering the significant benefits that may be obtained from addressing the listed issues and reconsidering the way electricity tariff are implemented in the country, this thesis proposes a tariff re-balancing policy. The aim is to provide insight on how to achieve economic efficiency, including environmental costs, that provide long-run sustainability of the system by a reduction of the subsidy burden to the government and the utilities and decreasing the inclusion error of the current energy subsidy by improving the targeting mechanism. Nonetheless, re-distributional objectives should also be considered to achieve an important objective of the government, thus different potential alternatives are analyzed.

The structure of this thesis is as follows. The first section presents the theoretical framework for tariffs. The second section includes a literature review of theoretical and empirical studies on the design, implementation and re-balancing of tariff schemes. A characterization of the Mexican scheme and its historical development is presented in the third section. Fourth section accounts for the re-balancing of the tariff scheme and the analysis of the results. Finally, conclusions and policy recommendations are presented in the fifth section.

2 | Literature review

As described by Stiglitz (2000), natural monopolies arise as a solution to a market failure classified as *incomplete markets*. Under this situation, the presence of two or more companies producing a good or service may be inefficient provided the increasing returns to scale due to the high fixed cost structure. It means that markets are not competitive, which is a usual situation in public services provision such as water, telecommunications and electricity. This involves a discussion, not only on how to provide them, but also on how to charge users for its consumption.

Economic efficiency, as a rule to price goods and services, states that the marginal price has to be equal to the marginal cost of producing one last unit. This issue has been studied since the last century for energy and water utilities (Agthe and Billings, 1987; Malko and Swensen, 1989; Parry *et.al.* 2014). As a result, developments around how those services should be priced have been achieved, some of which are described by Dutta and Mitra (2017) for electricity. However, other goals such as re-distribution of income and environmental externalities have been assessed. The former is usually the main objective of governments around the world. Thus, as remarked by Schoengold and Zilberman (2014), the complementarity between them is not accurately evaluated, resulting in severe inefficiency issues due to the tariff scheme design.

The re-distributional goals seek to diminish the economic burden of low-income households for the electricity consumed. This is usually accomplished through subsidies provided within the tariff scheme design. Nonetheless, as Angel-Urdinola and Wodon (2007), Komives *et.al.* (2009) and

Cardenas and Whittington (2019) observed, these subsidies tend to be regressive; it means, households in wealthiest quantile receive a greater proportion of subsidy than those in the poorest. This is particularly significant for the Increasing Block Tariff (IBT) structure, which is one of the most common pricing schedule applied worldwide (Dutta and Mitra, 2017). In which, as the authors highlight, the targeting mechanism for the subsidies is not appropriate.

This issues have been evaluated in different countries. In China, improvements in energy consumption, subsidy distribution and utility revenues have been observed from the transition from a flat-tariff to an IBT (Sun and Lin (2013); Li *et.al.* (2018)). These results are in accordance with the conclusions presented by Gong *et.al.* (2016) for the residential gas retail market considering the same pricing scheme. However, they also suggest that the IBT needs to be implemented with other policies in order to avoid higher income households from receiving larger subsidies. This issue, even if it is slightly corrected in contrast with a flat price, still being a main concern, as remarked by Cardenas and Whittington (2019)

Although some researches have observed a reduction in the consumption of energy and water as a result of the IBT (Baerenklau, Schwabe, and Dinar, 2014), major failures have been also observed. In the U.S., authors such as Agthe and Billings (1987), Borenstein2008 and Borenstein (2012) highlight how IBT fail to achieve objectives related with equity and re-distribution of income as expected. They note a tendency of higher shares of subsidy perceived by high income households, resulting in larger and inefficient rates of consumption.

In Mexico, Komives *et.al.* (2009) remark the failures of the IBT scheme applied since 1970's. The authors highlight an apparently regressive incidence of subsidies in nominal terms. This is evaluated comparing the share of subsidies received by households in the lower energy consumption deciles and those in the higher. Their results show that, in 2005, the three first deciles accounted for 16% of the subsidies, while the top three receive the 39%. Thus, they analyse four different al-

ternatives to improve the results in terms of re-distribution of income and subsidy allocation. Those were: (1) modifications to the DAC (High Consumption Residential Tariff), (2) the implementation of a National Volume Differentiated Tariff (VDT), (3) a means test scheme linked with other social programs already implemented and (4) the reduction of the supply cost. As mentioned by the authors, the cost-reduction scenario is a cross-sectional alternative to the other three. On the other hand, Espinosa and Rosellón (2017) present an incentive price-cap mechanism applied to the isolated electricity system of Southern Baja California. This system, as the rest of the Mexican electricity system, corresponds to a meshed network where nodal pricing is used. They observe that significant gains can be obtained in social welfare in comparison with the transmission tariffs set by the regulator. Here is important to consider that, as Green (2007) remarks for the United Kingdom, nodal pricing also imply further attention on how the final tariff is set. This is a result of a major complexity and the compelling improvements that an effective optimal pricing may have on social welfare and power generators revenues.

Other countries such as Ghana (Whittington, 1992), Israel (Dahan and Nisan, 2007), Cape Verde, Rwanda, Sao Tome and Principe (Angel-Urdinola and Wodon, 2007), Peru (Barde and Lehmann, 2014, India, Kenya (Fuente *et.al.* 2016), Taiwan (Hung and Chie, 2017) and Etiophia (Cardenas and Whittington, 2019, report similar conclusions as a consequence of the implementation of IBT schemes. This is mainly regarding to the limitations in the mechanisms used to target the subsidy appropriately. Hence, the IBT does not meet the main objective of governments. Additionally, as a result of this issue, financial security of utilities is not guaranteed, given the low rate of revenue stemmed from the large subsidies required.

On the other hand, the inclusion of environmental costs (those associated with the energy generation process) for the optimal electricity pricing scheme have also been assessed. Parry *et.al.* (2014) develops an analysis on how externalities derived from energy generation, such as GHG, should be accounted in the final tariff calculated. As a result, an optimal tariff, which accounts

not only for the private marginal cost, but also the social marginal cost, is obtained. This represents improvements in the social welfare. Later, Kejser (2016), studied the effect of individual information about environmental externalities in the consumer attitude toward higher tariffs for water, finding a positive impact. Also, Friedman (2011), analyses the effect that the inclusion of the marginal cost in the final tariff may have in GHG reduction programs in the United States. His results show that Time-Of-Use (TOU) rate schedules lead to improvements in the final price perceived by consumers, but requires the full deployment of *smart-meters*, which covered only 9% of U.S. household in 2011.

Also, a focus on economic efficiency have been made by other authors for different utility services. Passey *et.al.* (2017) present a method to visualize how cost-reflective a tariff scheme is. This with the aim of providing policy recommendations so households with a higher consumption during peak hours, raising the price due to the congestion costs, face a higher economic burden. His results suggest that this approach facilitate the allocation of the costs faced by power companies in Australia, including marginal costs in the short and long term. Borenstein (2013) analyses the impact of a dynamic pricing scheme which considers marginal prices. As observed by the author, the proposed alternative would give incentives to consumers to reduce electricity consumption and to integrate alternative technologies such as wind and solar to the energy mix of a country. This provided that dynamic pricing allows to match demand with supply fluctuation in a more efficient way, reducing the cost related with the integration of those technologies.

Additionally, Nataraj and Hanemann (2011) showed, through a regression discontinuity design, that consumer do respond to changes in marginal prices. Their results show a reduction of 12% in consumption when marginal prices are doubled. This reflect how incentives for the reduction of consumption levels can be obtained from an economic efficient scenario. Madureira (2014) reviews how the marginal cost pricing have been conducted in the past century and Di Bella and Grigoli (2017) analyse different economic equilibrium under various tariffs scheme. In their research,

the cases of Haiti and Nicaragua are evaluated while accounting for economic efficiency. Their results show that it is possible to get to an equilibrium were improvements in electricity costs, electricity shortages and regressive subsidies, fraud and non-payment could be achieved. Also Reynaud (2016) assessed the impact that a strategy of full cost recovery through marginal prices and fixed cost have in the consumption of some Europeans countries. His findings suggest that only low income households faces significant affordability issues, which may be attended with complementary policies to achieve re-distributional goals. Thus, this work will evaluate the effect of an economic efficient re-balancing of the electricity tariff in Mexico considering alternative to make it compatible with re-distributional an environmental goals.

3 | Tariffs

From the economic efficiency perspective under perfect competition, firms will set a price (p) that equals the marginal cost (c) of supplying the good or service. Under this scheme, the firm covers its costs, and thus, will keep participating in the market. When externalities are taken into the problem, the total marginal cost, which is divided into the private and the social marginal cost, determines the optimal price. Further analysis has been made, where the primary objective is to maximize not only the firm surplus, but also the consumer surplus as presented by Ramsey (1927). His work theorizes a notion of utility pricing that allows them to obtain the revenue needed to cover their costs, minimizing the total surplus loss. This is, indeed, an extension of the price-discrimination theory.

As described by Wolak (2008), in a simple scenario with a homogeneous product, increasing returns to scale and a market of N individuals where each pays a specific price, the goal is to maximize the total surplus with the constrain of cost recovery: $F \leq \sum_i S_i(p_i)$, where F represents the fixed cost of the utility and $S_i(p_i)$ denotes the consumer surplus of household i. Also, assume that $T_m(p_h)$ denotes the producer surplus for each of the M companies. Then, the objective is to maximize the Total Surplus (TS) subject to the cost recovery constrain, where

$$TS = \sum_{i}^{N} S_i(p_h) + \sum_{m}^{M} T_m(p_h)$$

From which the following result can be obtained

$$\frac{p^* - c}{p^*} = -\frac{k}{\eta}$$

Where k is a non-negative constant and η is the price-elasticity of the good. Considering this, the optimal pricing scheme charges each user according to its consuming behavior. So, higher prices for inelastic goods in comparison with more elastic goods are observed; which tends to be the case of electricity (Borenstein, 2008). From this, it can be considered that fixed cost may be stated according to the willingness of each individual to pay. Limitations of the *Ramsey Prices* have been remarked by Shepherd (1992), such as its complexity when there are competitive interactions and the omission of goals of equity and innovation. Nonetheless, their usefulness to minimize welfare loss while allowing for cost recovery have been observed in different contexts (Bigerna and Bollino, 2016).

In general terms, different tariffs schedules have been developed and applied, Dutta and Mitra (2017) listed nine commonly used schemes, with the simplest being the *Flat tariff*, in which the consumer pays the same amount of money notwithstanding power demand changes. Under this scheme, there is no incentive for them to reschedule their energy consumption, consequently, it may not be the most appropriate scheme regarding economic efficiency or re-distributional objectives. Therefore, other schemes have been developed: *Block Rate Tariffs*, *Seasonal Tariffs*, *Time-Of-Use Tariff*, *Superpeak Time-Of-Use Tariff*, *Critical Peak Pricing*, *Variable Peak Pricing*, *Real-ime Pricing* and *Peak Time Rebates*.

Among these, nonlinear price schedules are usually applied, the most common being the multi-part rates case (Reiss and White, 2005), where the budget constraints of consumers are not linear. Thus, they face an entire price structure rather than an average price or a single marginal price, as the one mentioned previously. A usual form of the multi-part prices, the Increasing Block Tariff (IBT), was introduced to achieve income re-distribution goals. Its main assumption is that it will protect low energy consumption households, which are expected to have lower-incomes. Mean-

while their consumption does not exceed the threshold for the next block, this group will pay the lower price .

Thus, $J > 1$ blocks are defined, assigning a subsidy to the first $J - 1$. The remaining block is commonly assumed to be rated at the long-run marginal cost (LRMC) (Schoengold and Zilberman, 2014), thus economically efficient pricing within the context of IBR can be achieved. This is an outstanding assumption, provided that according to Schoengold and Zilberman (2014) "if the higher block price is above the LRMC some individuals will under consume relative to the economically efficient outcome". Nonetheless, this is far from the actual rate structure usually applied, where households in the last block tend to face prices significantly above the LRMC. Thus, within the IBT schedule, marginal cost does have implications on the way consumers take decisions about their energy usage. Nataraj and Hanemann (2011) note that, under utility-maximization theory, consumers will react to marginal cost shifts in the block where they are consuming and in those below it.

Given the above, a simple example of the IBT scheme can be represented as follows. Consider a two-block scheme. If the electricity consumption of a household during the period falls in a certain range $(x_0, \bar{x})$, it faces a price $\$P_1$ per kilowatt-hour (kWh). Above the upper limit of this range, $[\bar{x}, \infty)$, the household should pays a higher rate of $\$P_2$ for each kWh consumed during the period. Therefore, each household i faces a cost function that depends on the quantity of electricity consumed. Yet, this may also depend implicitly on socioeconomic variables such as income of the household and the number of members living in it, included in the parameter Y of the demand function $X(p, Y)$ and the utility function described below. The cost function $c(x_i)$ is given by equation (3.1). The structure described is exemplified in Figure 3.1.

$$c(x_i) = \begin{cases} xP_1 & \text{if } x < \bar{x} \\ \bar{x}P_1 & \text{if } x = \bar{x} \\ (x - \bar{x})P_2 + xP_1 & \text{if } x > \bar{x} \end{cases} \tag{3.1}$$

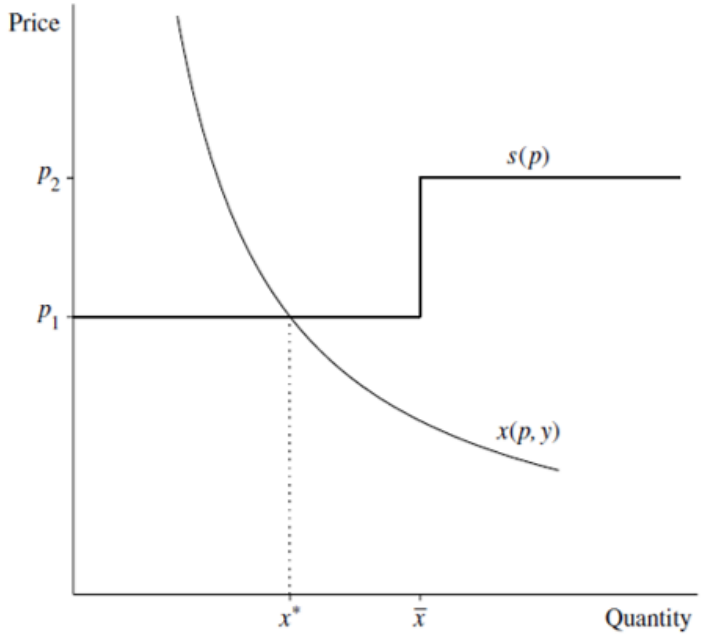

Figure 3.1: Increasing Block Tariff with two blocks

Source: Reiss and White, 2005

Then, each household will consume the quantity of q that maximize its utility, which may be expressed as

$$U(Y, x) = B(Y, x) - c(x) \tag{3.2}$$

Where $B(Y, x)$ represents the current benefit for electricity consumption. However, as can be inferred by the presence of *Y*, the decision of each household on how much electricity consume over a period does not depend only on how much they earn. Other variables such as the number of members of the household, the quality and age of their appliances, among other, will have an impact on the final level of consumption. Provided this, the main assumption of IBT scheme may fail due to a wrong targeting mechanism for the subsidy. This will result not only in the lack of

economic efficiency, but also in distributional and equity issues, as observed in previous literature. Therefore, an excessive subsidy and financial limitations of utilities due to the low cost-recovery rate rises (Cowan, 2004; Komives *et.al.* 2009).

Considering the differences between the structures mentioned, the shift from one to another will impact the welfare of individuals, which may be measured through changes in the consumer surplus (CS). It may be expected that households which used to consume quantities rated above the marginal cost will perceive an increase in their welfare, provided lower charges for each kWh consumed. The opposite will happen for individuals that previously faced rates under the marginal cost. Nevertheless, the magnitude of this variation depends of the price elasticity of consumers. Considering this, a constant-elasticity demand curve of the form $q = \alpha p^{\eta}$ will be assumed, where α is a non-negative constant and η is the price-elasticity of electricity. This re-distribution of consumer surplus will lead to an economically efficient equilibrium. This means the demise of the subsidy and the recovery of all the costs incurred by the utility.

However, with the improvements in economic efficiency stated the objectives of income re-distribution vanish. This, given that households in lower-income deciles that paid a rate under the marginal cost will observe an increase in their bill. Thus, alternatives to remain attached to this set of goals and comply with the legal terms of rates must be assessed within the Mexican context.

4 | Mexican electricity tariffs

Utilities in Mexico must with different citeria from the legal framework [1]. On one hand, tariffs must be calculated considering economic efficiency and financial security criteria. For electricity, those rates are calculated by the independent energy regulator (*Comisión Reguladora de Energía*, CRE). The regulator must do it in a way that promote the efficient development of the energy sector, guaranteeing energy security and complete access to all market participants and final users. Moreover, the final tariff scheme must allow to recover efficiently the costs incurred by the residential energy supplier (*Comisión Federal de Electricidad*, CFE). On the other hand, the subsidy[2], must aim to the redistribution of income from high- to low-income households, reducing inequality among regions through the efficient use of resources.

The Federal Commission of Electricity (*Comisión Federal de Electricidad*, CFE) is the national public electricity utility. Previously to the Energy Reform applied in 2013, CFE operated as a natural monopoly in the energy industry. It included generation, transmission, distribution and retailing stages. However, exceptions were applied to small private companies which could: (1) produce and sell energy to CFE, (2) export energy and (3) and self-sufficiency. Nevertheless, this structure led to high and unstable energy costs given the increasing energy demand and the low rates of return perceived by CFE, which resulted in a significant constraint to the energy infrastructure expansion. After the reform, a new scheme for the electricity industry was established. On one hand, the gen-

[1] Law of State-like Companies (*Reglamento de la Ley Federal de las Entidades Paraestatales*), Article 26; Electricity Industry Law (*Ley de la Industria Eléctrica*), Articules 12 and 140.

[2] Federal Budget and Fiscal Responsibility Law (*Ley Federal de Presupuesto y Responsabilidad Hacendaria*), Articule 75.

eration and the retailing stages were opened to the private sector with the aim of increase national and international private investment in the sector. Nonetheless, transmission and distribution stages kept being CFE responsibilities. Also, the National Center for Energy Control (*Centro Nacional de Control de Energía*, CENACE), which was an internal area of CFE, started to operate as the independent regulator of the wholesale electricity market (day-ahead and spot markets) and the middle and long-run energy auctions. The final goal of this reform was to open the electricity market, increasing the levels of competitiveness in the sector and reducing costs and economic burdens of CFE. This was expected to reduce the final price faced by consumers in the middle- and long-run. However, adjustments to this structure are under assess by the new government.

On the other hand, the electricity tariff scheme remains stable. The IBT applied in the residential sector implemented in Mexico consist on seven different groups. Each of those groups are divided into different blocks that vary according to the geographical area and the season of the year. They are denoted by 1, 1A, 1B, 1C, 1D, 1E, 1F. For this seven groups no fixed charge is applied and the variable charge depends on the consumption block and the season of the year. Additionally, there is a High Consumption Residential Tariff (*Domésticas de Alto Consumo*, DAC), which is applied when the average consumption of a household surpasses the threshold of the category to which it belongs. The final goal of this scheme is to reduce the economic burden to households in geographical regions where the average temperature during the year is higher, especially during summer season. In contrast with areas with lower average temperatures, households in these zones are expected to consume more energy due to the usage of air conditioner and refrigerators. Then, higher subsidy rates are observed there. Given that each group has different blocks which vary according to the season, the Mexican IBT scheme has more than 100 billing possibilities for residential customers.

A summary of the 2019 structure for the month of March is presented in Table 4.1. For this month summer season tariffs are applied. As observed, a household in the category 1F may con-

sume ten times more energy in the fourth block than a household in the category 1 in the third block, while facing the same price. Even at the lower level of consumption, category 1 pays 36,15% more for each of the first 75 kWh than the price paid for each of the first 300 kWh consumed by a household in the category 1F. Thus, it is clear how the length in kWh of each block increases for each category. This has significant implications on the share of the subsidy assigned to each of them. This is especially notorious for those with the highest average temperature during summer. A Household which its average consumption during six billing periods is beyond the higher threshold defined for its group is automatically classified as DAC. In this category, a different price is applied according to the Regional Control Center to which it belongs. This price is around 50% higher that the actual marginal cost. For this category, a fixed and a variable charge is enforced according to the season of the year and no subsidy is assigned. This could be considered a cross-subsidy from DAC households to other users. However, the low number of household the Table 4.2 presents the variable rate for each region. As observed, the cost of each kWh is considerably higher than the other 7 categories, even for the last blocks. In addition, for the month of March of 2019, the fixed charge was $107,37 MXN for all regions.

Table 4.1: Residential tariffs groups and blocks in the Mexican IBT scheme

Group	MATS [1]	Summer	Block [2]				DAC [3] [4]
			1	2	3	4	
1	25 C°	No	0 - 75 kWh $0.043	75 - 140 kWh $0.052	140 - 250 kWh $0.152	-	>250
1A	25 C°	Yes	0 - 100 kWh $0.038	100 - 150 kWh $0.044	150 - 300 kWh $0.152	-	>300
1B	28 C°	Yes	0 - 125 kWh $0.038	125 - 225 kWh $0.044	225 - 400 kWh $0.152	-	>400
1C	30 C°	Yes	0 - 150 kWh $0.038	150 - 300 kWh $0.044	300 - 450 kWh $0.057	450 - 850 kWh $0.152	>850
1D	31 C°	Yes	0 - 175 kWh $0.038	175 - 400 kWh $0.044	400 - 600 kWh $0.057	600 - 1000 kWh $0.152	>1000
1E	32 C°	Yes	0 - 300 kWh $0.032	300 - 750 kWh $0.039	750 - 900 kWh $0.051	900 - 2000 kWh $0.152	>2000
1F	33 C°	Yes	0 - 300 kWh $0.032	300 - 1200 kWh $0.039	1200 - 2500 kWh $0.096	2500 kWh $0.152	>2500

[1] Stands for Minimum Average Temperature During Summer.

[2] Prices are presented in USD/kWh

[3] DAC tariff is applied when the average consumption of the last six billing periods surpasses the threshold

[4] Rates for DAC category differ by Regional Control Center, see Table 4.2

Source: Own calculations using CFE, 2019 data.

Table 4.2: DAC rates for each Regional Control Center during summer

Region	Variable charge ($USD/kWh)
Baja California	0.259
South Baja California	0.283
Central	0.267
Northwest	0.250
North and Northeast	0.244
South and Peninsular	0.247

Source: CFE, 2019

This scheme results of decades of modifications and adjustments of the groups and their blocks, since it was first proposed in 1973. The initial stage considered only one tariff classification and three blocks, with subsidies for the first two. However, important changes have been made over the years, resulting in considerable increases to the subsidies. This increment, jointly with the rise in costs of energy distribution, has resulted in the detriment of the financial situation of the CFE. Thus, the reality is far from the legal framework that is supposed to govern this scheme.

As mentioned, the cost of providing the electricity has an outstanding role in the amount of the subsidy and the distributional incidence of it. In Mexico, a nodal pricing structure is applied, where nodes are classified according to the region to which they belong. The National Electric System is divided into three sections: the National Interconnected System, the Baja California Interconnected System and the Baja California Sur Interconnected System. Those areas are divided into eight Regional Control Centers, distributed as shown in the figure 4.1.

In each node, the Marginal Local Price is calculated hourly in the Day-ahead and the Spot market. The resulting prices consider the actual cost of electricity generation (the energy component), a component of losses and a component of congestion. This desegregation provide information about investment needs in generation and transmission, so the general cost of electricity may be reduced in the middle- and the long-run. According to the List of Nodes published by the CENACE, in

Figure 4.1: Regional Control Centers

Source: CENACE, 2018

2019, 2,463 nodes existed; most of which were located in the occidental region, with 697 nodes.

It is important to highlight that, in terms of economic efficiency, the local marginal price calculated for the node to which a household is connected, is the price that each should pay for the energy consumed during the day. Furthermore, as Passey *et.al.* (2017) argue, the final price faced for each household should be weighted by its contribution to the demand. This especially during the peak-hours, where congestion costs increase the average price paid for all users. Furthermore, given the overload of energy demand, generation plants with higher levels of pollutant emissions are required to operate, rising the social marginal cost due to the externalities. Nonetheless, provided the technical and infrastructural needs of this cost-reflective tariffs, they are not feasible yet in the Mexican context. So, the average marginal price during the billing period of each node may be used. Thus, the IBR scheduled used, the high levels of subsidy and the way electricity costs are calculated add complexity to the effective approach to an optimal pricing schedule in Mexico.

5 | Data

Three main databases were used for the tariff re-balancing proposal. First, hourly energy demand information for each Regional Control Center between June and November 2016[1] was gathered from the CENACE, from which an average demand per hour in each region was calculated. The resulting values are charted in Figure 5.1, where each point represents the share of energy demand at a specific hour from the average daily demand for the months considered. As expected, energy demand increases sharply before 6 in the morning for most of the Regional Control Centers. Also, peak-hours occur after the 18 hours for most of them. However, Northeast region has an average demand that remains stable between 4% and 4.4% during the day. This region has a higher consumption than the others, with an average total daily demand of 257,679 mWh. This is the result of a larger population consuming a significant and constant amount of energy during the day, given the use of appliances such as air-conditioner and refrigerators.

The previous procedure was used to weight the marginal prices for nodes in each region according to the average hourly consumption in it, so an approximation to a cost-reflective price may be calculated. It means, marginal costs in peak-hours will represent a greater share of the final price assigned to each location to which the connection point belongs. This marginal prices were obtained from the CENACEs' daily nodal pricing reports, each of which was matched with a Regional Control Center (and a location that was later used) according to the List of Nodes published by the same institution in 2016. For the period of time studied, the weighted average price of 814

[1] The period of time studied corresponds to the months in which the 2016 National Survey of Household Income and Expenditure was conducted, thus the data may be cross-matched in later stages.

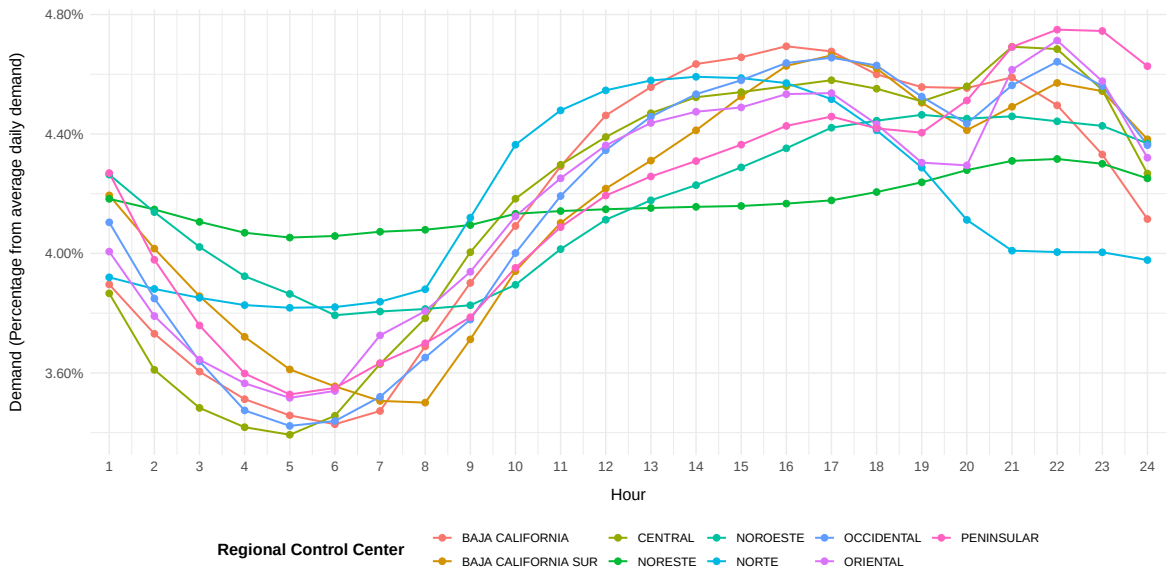

Figure 5.1: Average hourly energy demand

Source: Own calculations using CENACE, 2016 data

nodes and its corresponding location was obtained.

Figure 5.2 presents the marginal prices for the nodes in each region highlighting the minimum and the maximum value. As observed, South Baja California region has the higher marginal prices, fluctuating between 134.71 USD/mWh and 144.54 USD/mWh, with an average value of 139.68 USD/mWh. This occurs whilst its average total daily consumption is the lowest among all the regions. Thus, the difference in prices between this region and the others may be due to the lack of infrastructure and the high congestion costs stemmed from it. Then, provided that the rate category in this region is 1F (thus, the higher subsidies are assigned there), significant consumer surplus shifts are expected with the implementation of the proposed rate schedule. In contrast, the lower marginal prices are observed in the Baja California region, varying between 37.76 USD/mWh and 39.79 USD/mWh, and an average value of 37.76 USD/mWh. For this area, the average total daily consumption only exceeds the one from Southern Baja California and Peninsular regions. For the rest of the control centers, the marginal price ranges around 40 USD/mWh and 60 USD/mWh, with the large majority of the nodes located in the Western and Eastern regions. This marginal prices

corresponds only to variable costs, fixed cost will be later approximated.

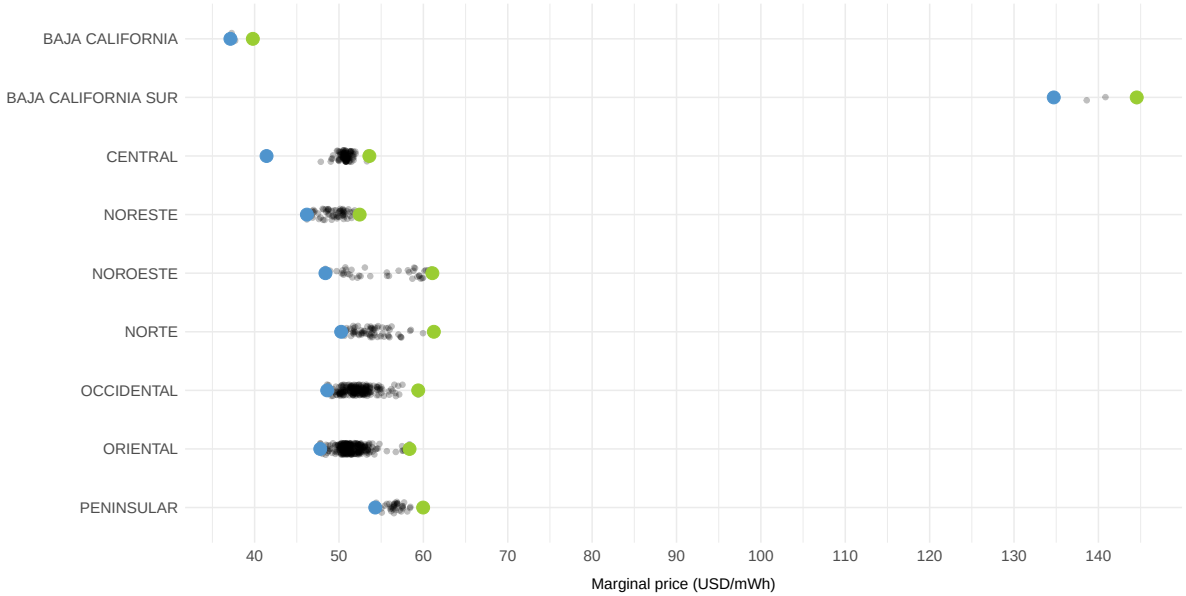

Figure 5.2: Marginal prices by Regional Control Center

Source: Own calculations using CENACE, 2016 data

On the other hand, the primary source of information for the analysis was the National Survey of Household Income and Expenditure (*Encuesta Nacional de Ingreso y Consumo de los Hogares*, ENIGH) of 2016 delivered by the National Institute of Statistics and Geography (*Instituto Nacional de Estadística y Geografía*, INEGI). The survey was conducted between June and November of 2016. It provides information about 60,808 Mexican households' income and expenses as well as their demographic characteristics and attributes of the housing unit infrastructure and equipment. The data provided by INEGI includes a expansion factor for each household, which will be used to achieve national representativeness. Nonetheless, observations whose general expenditure were below the first percentile and above the ninetieth percentile were dropped. This, given that most of them either report an extreme low expenditure and high income or and extreme high expenditure and low income. Also, observations with missing values of variables of interest, such as energy consumption level or socioeconomic characteristics were omitted. Thus, 52,772 observations remain, which, due to the expansion factor, represent 25,253,033 households. On the other hand, the general expenditure reported by each unit was used as the relevant variable rather than income,

Table 5.1: Energy consumption related variables description

Variable	Units	Mean	Std. Dev.	Min	Max
Household members	Integer	3.71	1.82	1	21
Number of bedrooms	Integer	2.07	0.90	1	12
Number of rooms	Integer	3.86	1.52	1	23
Air conditioner	0/1	0.14	0.34	0	1
Boiler	0/1	0.48	0.50	0	1
Energy consumption	kWh	164.34	163.17	1.14	2,482.21
Energy expenditure	USD	20.53	26.23	0.11	642.10

Source: Own calculations using CFE and ENIGH, 2016 data

provided that the former tends to be reported more precisely. Moreover, the location of each households was used to match them with a marginal price, previously calculated for each node. It means, the marginal price that each household should pay depends on the node to which is connected, assumed to be the one in the same location[2].

Table 5.1 reports a summary of some relevant variables in the matter of energy consumption and the expenditure required to cover it. As seen, even thought the average number of household members, bedrooms and rooms of the housing unit may be considered low, they vary among a large range of values. Thus, households reporting a high level of expenditures not necessarily corresponds with those with higher payment capacity. Also, notwithstanding the low proportion of the population who own air-conditioners or heater systems, the energy consumption rate of this type of appliances is high. This implies an important increase in energy demand in those regions with extreme temperatures, where this kind of appliances is common. Also, an exchange rate of $18.6886 MXN/USD is considered. This value corresponds to the average exchange rate between June and November of 2016.

However, for the purpose of analyzing properly distributional and targeting issues, the sample is

[2] This method is used to obtain an approximation to the marginal price applicable to each household. Perfect matching requires administrative detailed data

divided into general expenditure deciles. From above, there are two relevant variables to consider. First, Table 5.2 presents the average energy consumption of each group. As expected, it increases as the general expenditure rises. Nonetheless, the minimum value for the last decile is approximately 11 kWh, exposing the presence of households with high-income (measured through general expenditures) which fall in the first block of its category. It means they receive a significant subsidy which they may not require. On the other hand, Table 5.3 leads to a similar interpretation about the electricity payments of households in the last decile. As mentioned before, this households may be constituted by an individual with high income and long working hours who stay out of home for long periods of time, leading to a low energy consumption.

Table 5.2: Average energy consumption (kWh) per expenditure decile

Decile	**Mean**	**Std.Dev.**	**Min.**	**Max.**
1	91.69	81.87	2.5	1179.6
2	119.14	105.66	4.55	1,201.50
3	133.54	116.72	6.83	1,404.85
4	143.93	128.07	4.50	1,472.19
5	160.16	150.20	6.00	1,696.63
6	161.82	146.13	1.14	1,853.75
7	181.72	167.21	8.01	2,078.20
8	195.36	178.79	8.54	1,853.75
9	215.39	203.10	5.69	1,853.75
10	241.35	234.60	11.01	2,482.20
Total	**164.34**	**163.17**	**1.14**	**2,482.20**

Source: Own calculations using CFE and ENIGH, 2016 data

On the other hand, the rate category for each household was determined according to their reported consumption during the billing period and their location. Table 5.4 summarizes the results. As observed, the categories which include the largest share of the population are 1 and 1C, with an average energy consumption of 104.96 kWh and 256.22 kWh respectively. The DAC rate is applied when a household average consumption during the last six billing period surpasses the

Table 5.3: Average energy expenditure in USD per expenditure decile

Decile	Mean	Std.Dev.	Min.	Max.
1	4.77	4.42	0.13	58.54
2	6.42	6.25	0.21	125.75
3	7.34	7.01	0.32	93.64
4	8.18	8.42	0.24	160.53
5	9.28	9.52	0.32	160.53
6	9.52	9.52	0.05	144.47
7	11.18	11.8	0.43	173.9
8	12.41	13.39	0.4	175.24
9	14.67	18.07	0.27	321.05
10	18.93	23.64	0.59	294.3
Total	**10.26**	**13.12**	**0.05**	**321.05**

Source: Own calculations using CFE and ENIGH, 2016 data

threshold described in Table 4.1. Given the maximum value of energy consumed in the DAC rate, only households from categories 1, 1A, 1B, 1C and 1D could have faced this shift. Hence, the DAC threshold imposed to households in the rates with higher subsidies may be considered grater than is actually required. This incentive higher consumption levels.

Table 5.4: Energy Consumption (kWh) by tariff category for the ENIGH 2016

Group	Households	Mean	Std.Dev.	Min.	Max.
1	14,681,554	104.96	52.44	2.50	457.73
1A	1,638,083	125.93	67.88	5.69	521.16
1B	2,985,801	148.62	87.94	1.14	688.01
1C	3,848,119	256.22	170.16	4.55	1,445.45
1D	751,179	324.37	207.85	17.08	1,406.87
1E	666,268	452.33	294.51	22.46	1,760.73
1F	636,669	642.85	370.27	17.70	2,482.20
DAC	45,360	413.83	205.79	253.88	1,322.41
Total	**25,253,033**	**164.34**	**163.17**	**1.14**	**2,482.20**

Source: Own calculations using CFE and ENIGH, 2016 data

Finally, failures of the targeting mechanism for subsidy might be also observed from the block in which a household consumption falls and the expenditure decile to which it belongs. Table 5.5 and Table 5.6 present such distribution for rates categories 1, 1A and 1B and 1C, 1D, 1E and 1F respectively. For the first group, as can be recalled from Table 4.1, the third block represents a noteworthy increase in the price for each kWh. Thus, blocks 1 and 2 have a large subsidy. For the second group, the large shift in prices occurs for the fourth tier. Hence, for the first three price categories, even in the higher expenditure deciles, the number of households which receive a subsidy overcomes those which consume in the third block. This is more severe in the second group, which already receive the larger share of subsidies due the average temperature in those areas. Here, the number of households in the three first block surpass significantly those in the forth, even for the higher expenditure deciles. Hence, from this first descriptive analysis, deep failures in the Mexican IBR schedule has been highlighted .

Table 5.5: Households in each block by expenditure decile - Tariff categories 1, 1A and 1B

Decile	**Block**			**Total**
	1	**2**	**3**	
1	1,351,392	594,544	107,352	**2,053,288**
2	959,000	783,285	183,545	**1,925,830**
3	804,828	894,455	263,674	**1,962,957**
4	685,680	946,480	325,641	**1,957,801**
5	565,995	922,487	398,655	**1,887,137**
6	482,523	1,005,607	437,015	**1,925,145**
7	405,884	969,568	522,855	**1,898,307**
8	314,280	961,047	621,466	**1,896,793**
9	250,195	866,139	743,020	**1,859,354**
10	195,348	764,927	978,551	**1,938,826**
Total	**6,015,125**	**8,708,539**	**4,581,774**	**19,305,438**

Source: Own calculations using CFE and ENIGH, 2016 data

Table 5.6: Households in each tier by expenditure decile - Tariff categories 1C to 1F

Decile	Block				Total
	1	2	3	4	
1	315,091	138,498	20,445	4,460	**478,494**
2	296,442	238,189	38,968	14,935	**588,534**
3	253,966	249,365	58,128	23,984	**585,443**
4	203,997	254,499	80,660	31,640	**570,796**
5	176,237	320,652	89,114	34,446	**620,449**
6	157,610	312,928	96,000	42,148	**608,686**
7	109,504	317,359	128,645	71,896	**627,404**
8	81,009	294,425	141,196	102,702	**619,332**
9	73,587	268,649	154,585	152,496	**649,317**
10	24,987	159,645	156,171	212,977	**553,780**
Total	**1,692,430**	**2,554,209**	**963,912**	**691,684**	**5,902,235**

Source: Own calculations using CFE and ENIGH, 2016 data

6 | Tariff re-balancing results

As mentioned above, economic theory sets the optimal price for a good in its private marginal cost of production. When accounting for externalities, an extra value should be considered so the social marginal cost is covered. For this, emission factors provided by SENER (2017) were used. Those factors were: 0.00283 kg/kWh for SO_2, 0.00186 kg/kWh for NO_X, and 0.47753 kg/kWh for CO_2, which are polluters stemmed from the energy generation process with fossil fuels. The corresponding price for each of these factors were US$70 per ton of SO_2 and US$16 per ton of NO_X and US$33.60 per ton of CO_2 (Nordhaus, 2016). From the above, the resulting cost of air pollution was $0.0162 USD/kWh. This value should be added to the marginal local price calculated for each node.

On the other hand, fixed cost were calculated considering the revenue requirements of CFE. This included costs related with the supply, distribution and transmission of energy, as well as the operation of CENACE, capacity and related services not included in the wholesale electric market. This set of costs accounts for the installation, operation and expansion of the required infrastructure for the provision of energy. Furthermore, the distribution system is divided into 16 divisions, each of which faces its own congestion costs and variations in the local marginal prices. Since 2017, the electricity bills present the different components of the total cost, for both, fixed and variable costs.

Afterwards, the total green tax collected was calculated as the average pollution cost times the total residential consumption in each distribution region. This amount and the variable cost were then subtracted from the revenue needs calculated before. This with the aim of use the green tax as

a way to reduce the final fixed charge faced by consumers, but not as an extra source of income for the government. Thus, households with higher level of consumption make a higher contribution to cover fixed costs and reduce the economic burden faced by other households. Finally, the last amount calculated was divided between the number of households in each division, so an approximation of the regional requirements could be obtained.

From this, the distribution of the subsidy among households was calculated as the difference between the actual cost and the expenditure on energy of each household. This is presented in Table 6.1. As observed, the average amount of the net-subsidy increases for higher income deciles. However, it is clear that, seen as a share of the income (measured through total expenditures), lower deciles perceive a higher subsidy. Nonetheless, high income deciles should not receive a direct subsidy, provided their payment capacity. Hence, a wrong targeting mechanism has been used to distribute electricity subsidies among Mexican households. Similar subsidy distributions has been highlighted by Cardenas and Whittington (2019).

6.1 Economic efficiency and externatlities

A first scenario of full revenue recovery for utilities was evaluated. It considered the local marginal prices (with the added cost of environmental externalities) and an equal distribution of the fixed cost among households, in which the green tax recovery was already subtracted as described before. This baseline scenario represents an economic efficient outcome, where the government subsidy is completely eliminated.

The changes in consumption are then estimated assuming a constant elasticity demand function, with a price elasticity for electricity of -0.22, estimated by Hancevic and Lopez-Aguilar (2018) for the Mexican context. The results of this baseline scenario are presented in Table 6.2, where changes

Table 6.1: Energy subsidy by expenditure decile

Decile	Subidy (USD)		Subsidy as a share of expenditures	
	Mean	**Std. Dev.**	**Mean**	**Std. Dev.**
1	10.74	5.68	3.49%	1.98%
2	12.34	7.21	2.28%	1.36%
3	13.12	7.94	1.82%	1.11%
4	13.50	8.45	1.52%	0.95%
5	14.32	10.01	1.35%	0.94%
6	14.27	9.72	1.13%	0.77%
7	14.97	11.06	0.99%	0.74%
8	15.35	11.63	0.84%	0.64%
9	15.46	13.18	0.65%	0.56%
10	14.27	14.45	0.38%	0.40%
Total	**13.83**	**10.35**	**1.45%**	**1.35%**

Source: Own calculations using CFE and ENIGH, 2016 data

in consumption and energy expenditure by decile are contrasted with those from the current pricing schedule. As observed, households in the first expenditure decile reduce their consumption in a range between 0,45% for the fifth decile, and 4.6% for the first decile. In contrast, their energy expenditure increases in more than 100%, with the first decile facing the largest shift (181,36%). On the other hand, last deciles increase their consumption, with the largest increment observed in the group with higher income level (6.85%). Meanwhile, this group faces the lower rise in their final energy expenditure. This is an expected result. Provided that most households in the first deciles were located in the lower blocks where prices are below the marginal cost, they would perceive the higher impact. This means that those households faced an increment in the price per kWh, especially in those areas where local marginal prices were significantly higher, as observed in the Baja California region. The opposite situation occurs in households in the last deciles, which, on average, perceived a reduction in the price paid. This provided that most households in the last deciles faced a price above the marginal price. However, it is important to highlight that, even if

these results are efficient in economic terms, could not be considered fair. This will be discussed with more detail.

Table 6.2: Changes in energy consumption and energy expenditure by decile

Decile	Energy consumption (kWh)			Energy expenditure (USD)		
	Current pricing schedule	**Baseline scenario**	**Percentage change**	**Current pricing schedule**	**Baseline scenario**	**Percentage change**
1	91.89 (81.86)	87.66 (79.21)	-4.60%	4.78 (4.42)	13.45 (7.28)	181.36%
2	119.19 (105.70)	115.32 (104.33)	-3.25%	6.42 (6.25)	15.60 (9.50)	143.10%
3	133.56 (116.87)	130.69 (116.36)	-2.15%	7.34 (7.02)	16.60 (10.25)	126.32%
4	144.01 (128.12)	142.66 (130.59)	-0.94%	8.18 (8.42)	17.46 (11.42)	113.37%
5	160.63 (150.40)	159.91 (151.92)	-0.45%	9.31 (9.53)	18.79 (12.98)	101.86%
6	162.03 (146.39)	162.30 (148.28)	0.17%	9.54 (9.54)	18.91 (12.86)	98.27%
7	182.14 (167.40)	184.52 (172.42)	1.31%	11.21 (11.82)	20.55 (14.73)	83.32%
8	195.59 (178.97)	200.73 (187.56)	2.63%	12.42 (13.41)	21.62 (15.70)	74.00%
9	215.80 (203.25)	224.57 (215.59)	4.07%	14.70 (18.08)	23.33 (17.91)	58.69%
10	241.58 (234.76)	258.13 (255.77)	6.85%	18.95 (23.66)	25.52 (20.67)	34.66%
Total	**164.57** **(163.35)**	**166.57** **(171.27)**	**1.21%**	**10.28** **(13.13)**	**19.18** **(14.29)**	**86.57%**

Standard deviations in parenthesis

Source: Own calculations using CFE and ENIGH, 2016 data

6.1.1 Inefficiency and Consumer Surplus

Provided the previous results, two measures of inefficiency and welfare variations could be evaluated. In the first case, the losses and gains due to the IBT scheme could be observed from the difference between the consumption (or energy produced) at the original prices and those consumed (produced) under the economic efficient scenario. It means, households which belong to a block with a price lower than the marginal cost, consume more than they should according to the economic efficiency precept. The opposite occurs for households in blocks which face a price higher than the marginal cost. Thus, the amount of energy and the allocation of those units is inefficient and represent losses to the government due to the subsidy needed to cover the units priced at a lower cost than they should be. This loss was calculated according to Davis (2013). As shown in Table 6.3, the inefficiency stemmed from the IBT scheme is, as expected, larger for the last deciles. This means that the price paid for household in this group is significantly higher than the marginal cost. Thus, they are paying for non-consumed units.

Table 6.3: Inefficiency from the IBT scheme by expenditure decile (USD)

Decile	**Inefficiency**		**Total by decile**
	Mean	**Std.Dev.**	**(Thousands)**
1	0.18	0.84	1.25
2	0.35	1.29	2.23
3	0.49	1.55	2.90
4	0.63	1.83	3.92
5	0.78	1.97	4.60
6	0.85	2.04	4.88
7	1.14	2.45	6.11
8	1.45	2.87	7.59
9	1.90	3.36	9.73
10	2.74	4.01	12.52

Source: Own calculations using CFE and ENIGH, 2016 data

On the other hand, the inefficiency in the first deciles is lower, given that the distance between

the marginal cost and the price paid by households in this area, is relatively low. This occurs because most of the households in the first deciles belong to the block 1 or 2, which prices are close to the marginal cost in contrast with blocks 3 and 4. This inefficiency represents a loss of approximately $12.52 thousands of USD , only for the last decile. These results represents the potential improvement that the government could perceive if economic efficiency were the prime goal for setting electricity rates. On the other hand, the results presented above could be contrasted with the variation in the consumer surplus due to the shift in prices. Thus, this results consider only the variation in variable costs. The results shown in Figure 6.1 are congruent with the observed results in the previous subsection. Households in lower deciles, most of which belongs to blocks 1 and 2, face an increment in the price per kWh, reducing their consumer surplus. The most significant shift for low-income deciles is observed in the first one, with an average reduction of $1.25 USD per household. On the other hand, the tenth decile has a meaningful increase of $10.76 USD per household. Once the fixed cost, which average value among distribution regions is $8.31 USD is discounted, only the tenth decile still facing an average positive shift in its consumer surplus of around $3.05 USD.

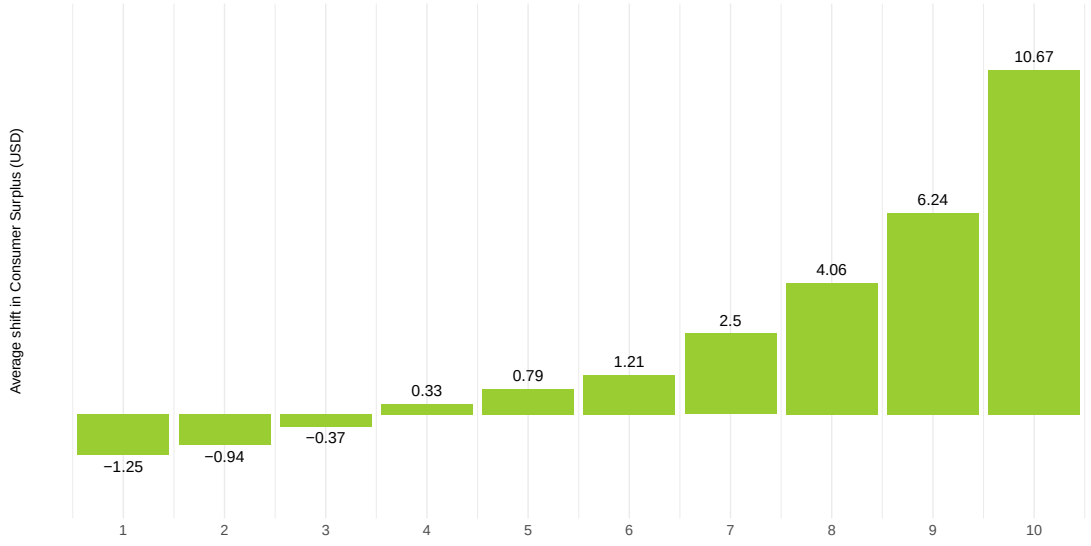

Figure 6.1: Variations in Consumer Surplus by expenditure decile under economic efficiency

Source: Author

From this first analysis, two major beneficiaries could be identified. First, the government and CFE will face a complete reduction of the subsidies. As a result, financial sustainability and security will be achieved. This could provide the necessary budget to carry improvements in the generation and transmission infrastructure. Such investments will result in a reduction of the costs faced by the utility, which could be transmitted to users in the middle- and long-run. It means, there will be a reduction in prices and fixed charges to all households, as well as a more secure electricity service. On the other hand, high-income households also have important welfare improvements from the new price scheme. This as a result of the reduction of the price per unit of energy consumed, which does not overcome the fixed cost charged. However, although this strategy accomplish economic efficiency and environmental goals, is far from being considered fair. Low-income households are facing a negative impact, which does not meet issues related to the re-distribution of income stated by the government.

6.2 Re-distribution of income strategies

As mentioned in the previous section, the pure economic efficient strategy is far from the re-distributional goals set by the government. Higher burdens are imposed to households with lower income as an outcome of this new rates. Provided this situation, two additional scenarios are evaluated. Furthermore, considering that the reduction of 100% of the subsidy is not realistic, only a reduction of 30% of the subsidy is considered in order to set a plausible situation and illustrate distributional effects. This reduction, in practice, should be progressive. The first scenario considers a proxy *means test*. This is used to identify households that, due to their socioeconomic characteristics and the attributes of their dwellings, could be classified as low-income households, and should receive the subsidy. This method could be considered ideal. However the information required to obtain an accurate measure of each household means of life relays in surveys which are expensive in both, time and money.

For this, a regression of the total expenditure on socioeconomic and demographic characteristics of households and attributes of the dwelling was conducted. This included the ratio between the number of members of the household and the number of rooms (overcrowding), the age, gender and level of education of the household head. Also the income, the presence of kids and elder people, the total number of members, the ownership of the house, the number of rooms, the type of the dwelling (apartment or house), and variables related to the material of walls, floors and roofs were used. These variables were interacted with the distributional regions, in order to account for possible regional differences. The results from this regression are presented in the Appendix A7. Then, an index was created from the estimated expenditure, classifying households according to the estimated consumption into deciles. After this, the amount of the fixed charge for each decile was calibrated to cover the 30% of the total fixed cost requirements.

The second alternative scenario considers that it is possible to observe the real income of households and thus, to distribute the subsidy according to it. For this, it is assumed that the decile to which a household belong classifies it accurately. As a result, higher expenditure deciles will face a larger burden of fixed cost, which could be considered perfect targeting. For this alternative to be considered valid, correlation between household expenditure and the calculated index should exist. This will guarantee that the proxy method applied provides a good approximation to the current mean of life of households. Once the regression was ran, such correlation amounts to approximately 0.62.

A comparison between the variations in the electricity bill paid by households under these alternatives and the economic efficient and baseline scenarios is presented in Table 6.4. As observed, the baseline scenario represents the lower economic burden, provided a subsidy of 100% of the fixed cost and the lower prices in the firsts blocks. Under this scenario, the average energy expenditure of the first decile was $4.78 USD, while the last decile faced an average energy expenditure of $18,95 USD. These values represented the 1.52% and the 0.48% of the total expenditure of the

first and the last decile respectively. The efficient economic scenario carries the larger shifts, as expected from the results discussed above. Under such scenario, households in the first decile increase their average energy consumption in more than 100%, to $13.45 USD, which now represents an average of 4.38% of the total expenditure. On the other hand, households in the last decile face a slight increase in the average share of its expenditure assigned to energy (0.66%). Nevertheless, as mentioned in the previous section, this result could be considered unfair given that lower income households perceive a larger burden.

Because of this, the next two scenarios were considered. As it can be observed from the table, the Means test strategy does reduce the economic burden imposed to lower income deciles. For the first decile, the average energy expenditure is reduced to $6.73 USD, which represents the 2.13% of the total average expenditure. This is a result of the shift in prices, given that the fixed charge paid for that group is zero. On the other hand, the impact on higher deciles is lower than the one in the previous scenario; even considering the burden imposed by the amount of the fixed charge that is not subsidized.

These changes are a reflect of the effect that prices above the marginal cost paid for most households in these groups have over consumption. As mentioned previously, this would be an ideal, but expensive (in administrative terms), scenario. Under the assumption that the observed expenditure does reflect the real economic capacity of households (perfect targeting scenario), the economic burden due to the fixed cost is slightly re-allocated. Lower income households have a reduction in the average energy expenditure in contrast with the means test scenario, which is closer to the results observed under the current IBT schedule applied. Meanwhile, higher income deciles have a slight rise in their economic burden. From an income re-distribution of income perspective, this is an improvement in the final outcome.

These results are coherent with those obtained by Mcrae and Wolak (2019) for Colombia. Un-

der the assumption of a linear demand, the same behaviour is observed in the shift in consumption and distribution of income as a result of different strategies. Also, as Borenstein (2008) highlighted from his results, *mean-tested* programs do contribute to reduce failures of the targeting mechanisms for electricity subsidy as has been shown in this research. Which is also observed by Barde and Lehmann (2014) for water pricing in Peru. Thus, strategies focused on obtaining this type of results should be encouraged.

Table 6.4: Energy expenditure variations among the proposed strategies by expenditure decile

Decile	Current IBT scheme		Economic efficiency		Means test		Perfect targeting	
	USD/Month	Share of total expenditure	USD/Month	Share of total expenditure	USD/Month	Share of total expenditure	USD/Month	Share of total expenditure
1	4.78	1.52%	13.45	4.38%	6.73	2.13%	6.01	1.92%
	(4.42)	(1.39%)	(7.28)	(2.56%)	(6.29)	(1.96%)	(5.65)	(1.79%)
2	6.42	1.18%	15.60	2.89%	9.46	1.74%	7.96	1.47%
	(6.25)	(1.17%)	(9.50)	(1.79%)	(8.75)	(1.62%)	(7.62)	(1.42%)
3	7.34	1.02%	16.60	2.31%	11.11	1.54%	8.98	1.25%
	(7.02)	(0.98%)	(10.25)	(1.44%)	(9.59)	(1.34%)	(8.38)	(1.17%)
4	8.18	0.92%	17.46	1.97%	12.67	1.43%	11.35	1.28%
	(8.42)	(0.94%)	(11.42)	(1.28%)	(10.90)	(1.22%)	(9.86)	(1.10%)
5	9.31	0.88%	18.79	1.77%	14.49	1.36%	14.12	1.33%
	(9.53)	(0.90%)	(12.98)	(1.22%)	(12.53)	(1.18%)	(11.73)	(1.10%)
6	9.54	0.76%	18.91	1.50%	15.29	1.21%	15.82	1.26%
	(9.54)	(0.76%)	(12.86)	(1.02%)	(12.52)	(0.99%)	(12.05)	(0.96%)
7	11.21	0.75%	20.55	1.37%	17.53	1.17%	18.99	1.26%
	(11.82)	(0.79%)	(14.73)	(0.98%)	(14.29)	(0.95%)	(14.31)	(0.96%)
8	12.42	0.67%	21.62	1.17%	19.28	1.05%	20.84	1.13%
	(13.41)	(0.73%)	(15.70)	(0.86%)	(15.44)	(0.84%)	(15.48)	(0.85%)
9	14.70	0.61%	23.33	0.97%	21.70	0.90%	23.33	0.97%
	(18.08)	(0.75%)	(17.91)	(0.75%)	(17.73)	(0.74%)	(17.91)	(0.75%)
10	18.95	0.48%	25.52	0.66%	24.75	0.64%	25.52	0.66%
	(23.66)	(0.60%)	(20.67)	(0.55%)	(20.52)	(0.55%)	(20.67)	(0.55%)
Total	**10.28**	**0.88%**	**19.18**	**1.90%**	**15.29**	**1.32%**	**15.28**	**1.25%**
	(13.13)	**(0.97%)**	**(14.29)**	**(1.71%)**	**(14.49)**	**(1.27%)**	**(14.63)**	**(1.16%)**

Standard deviations in parenthesis

Source: Own calculations using CFE and ENIGH, 2016 data

7 | Conclusions

Considering the inefficiency and the subsidy target mechanism issues existing in the current IBT scheme applied in Mexico; this research analyses the distributional and welfare effects of a tariff re-balancing in terms of economic efficiency. Furthermore, environmental externalities stemmed from the energy generation process are included, so a social marginal cost per kWh consumed could be set as the optimal price. For this, nodal pricing information from CENACE were used, as well as data from CFE tariffs and prices and socioeconomic information of households in Mexico from the ENIGH 2016 survey.

From a first analysis, it was observed that high-income households, measured through household expenditures, perceived a direct subsidy. These results imply significant financial burdens to the government and the national electricity utility, CFE, which should cover the required subsidy;reducing its budget for middle- and long-run investments. Thus, the failures of the targeting mechanism have been identified. Considering that income re-distribution is the main goal set by the government for electricity tariffs, the above results in an important issue. On the other hand, due to the difference between the price faced by households and the social marginal cost, there is a significant inefficiency in the IBT schedule from an economic perspective. This as a result of both, household paying a price below the marginal cost, thus consuming more energy than they should, and household facing a price above the marginal cost, which are paying for non-consumed units.

The above provides evidence of the necessity of a re-balancing of the current pricing scheme.

Thus, a first economic efficiency baseline scenario is simulated. Under this, each household faces its corresponding social marginal cost (according to the amount of energy consumed during the period) and the fixed cost is equally distributed. The results represent significant improvements in the financial situation of CFE. Under a full cost recovery scenario, energy policies could be focused on promoting the investment in energy infrastructure according to the requirements of each distribution region. As a result, in the middle- and long-run, congestion costs could be decreased. Furthermore, energy security and stability, as well as affordability due to the reduction of prices, could be achieved. However, the distributional effects of this scenario, in terms of redistribution of social welfare, are not just; lower-income households perceive a larger economic burden. Thus, it is no realistic and should be evaluated carefully. Nonetheless, given its potential improvements for public finances, this scenario could be taken as the baseline for any further strategy.

Considering this, two approaches were evaluated. These scenarios, considered a 30% reduction of the subsidy, in order to illustrate, under a more realistic condition, possible distributional outcomes. The proxy *mean-test* scenario led to improvements in terms of income re-distributions. As a result, the economic burden imposed to low-income household were transferred to those in higher expenditure deciles. These results are coherent with those observed in previous literature for similar analysis in Colombia (Mcrae and Wolak, 2019) and Peru (Barde and Lehmann, 2014). Nonetheless, for this strategy to be applied adequately, primary data of all inhabitants should be gathered. Thus, its implementation cost will be significantly higher, reducing its feasibility. However, if means-test programs are considered as the baseline to numerous public policies and social programs, the investment required could be justified. This means, the gathered data could be used to accurately target different public initiatives and optimize the use of resources for this type of interventions and for the assignment of subsidies.

Examples of this type of programs within the Latin American context can be observed in different countries. In Colombia, the Identification System for Potential Beneficiaries of Social Programs

(*Sistema de Identificación de Potenciales Beneficiarios de Programas Sociales*,SISBEN) classifies the population through a score according to its socioeconomic characteristics. Then, it allows to determine objectively how to target public programs and subsidies. Likewise, the Household Targeting System (*Sistema de Focalización de Hogares*, SISFOH) in Peru, is used to identify people who belongs to prioritized population groups, so the state benefits could be assigned more accurately to them.

Finally, the third scenario assumed a perfect targeting mechanism. In this, the expenditure decile to which a household belongs accurately classify the population by its income level. Results show a significant improvement in re-distributional outcomes. The monthly bill faced by households in the first expenditure deciles is closer to those under the IBT schedule, while higher economic burdens are imposed to those in the latest. This distributional results are obtained while a 30% of the fixed cost is also recovered by the utility, representing partial improvements in its financial situation. However, more precise results could be obtained if administrative data of households energy consumption and expenditure were available.

These results provide insight of the current situations of the electricity pricing schedule in Mexico and of potential improvements that can be obtained from a baseline that promote economic efficiency. As observed, it is possible to evaluate scenarios where economic efficiency, environmental externalities and re-distributions of income can be progressively achieved. For this, further research and investment in the identification of the optimal targeting mechanism should be done. This with the aim of obtaining the largest improvements in public finances with the lowest impact on social welfare, especially for those in the lower expenditure deciles. Also, these strategies foster efficient levels of energy consumption while considering environmental externalities, providing alternatives to enhance national goals of energy efficiency and climate change. Thus, this study represents a contribution not only in an important research area, especially for developing countries, but also for a matter of public policies and the role of decision-makers. This while improvement in the

energy sector of the country is achieved and major goals with implications over the social welfare are progressively addressed.

A Proxy mean-test regression results

Table A.1: Mean-test index regression results

	Household expenditure coefficients
Overcrowding (=1)	-11.3356***
	(1.2045)
Household head level of education	
Baseline level: No education	
Preschool (=1)	-108.3606***
	(6.0882)
Incomplete elementary school (=1)	17.5922***
	(0.7752)
Complete elementary school (=1)	110.2878***
	(0.7935)
Incomplete high school (=1)	191.8273***
	(1.1507)
Complete high school (=1)	257.2384***
	(0.7983)

Incomplete prep school (=1)	389.0866***
	(1.2042)
Complete prep school (=1)	492.1105***
	(0.9047)
Incomplete undergraduate studies (=1)	782.2760***
	(1.2252)
Complete undergraduate studies (=1)	1135.4058***
	(0.9306)
Postgraduate studies (=1)	1861.6526***
	(1.3626)
Household members characteristics	
Household head age	11.4207***
	(0.0716)
Square household head age	-0.1030***
	(0.0007)
Female household head (=1)	-49.0637***
	(0.3963)
Kids (=1)	-109.0746***
	(0.4637)
Elder household members (=1)	-68.0791***
	(0.6356)
Number of household members	123.9028***

	(0.1447)
Owner (=1)	-162.3552***
	(0.4263)
Household class	
Baseline level: Unipersonal	
Nuclear family (=1)	185.6810***
	(0.6620)
Extended family (=1)	205.7748***
	(0.8136)
Compounded family (=1)	260.0663***
	(2.1295)
Co-resident group (=1)	693.0776***
	(2.7781)
Housing unit characteristics	
Number of rooms	132.6572***
	(0.1367)
Housing unit class	
Baseline level: Independent housing unit	
Department in building (=1)	211.6950***
	(0.8101)
Housing in a neighborhood (=1)	46.1402***
	(1.1030)

Housing or room in roof (=1)	13.0254*
	(5.4693)
Room (=1)	64.5460***
	(1.9179)
Housing unit walls	
Baseline level: Waste material walls	
Cardboard walls (=1)	-181.8518***
	(5.9147)
Asbestos sheet walls (=1)	12.5741**
	(4.5725)
Reed, bamboo or palm walls (=1)	-208.3887***
	(5.6855)
Embarro or Bajareque walls (=1)	-179.7334***
	(5.3416)
Wooden walls	-24.3644***
	(4.6819)
Adobe walls	-51.2058***
	(4.9794)
Septum, Brick or Stone walls	80.6423***
	(5.2279)
Housing unit roof	
Baseline level: Waste material roof	

Cardboard sheet roof (=1)	-92.0953***
	(4.3178)
Metallic sheet roof (=1)	-87.2678***
	(3.8698)
Asbestos sheet roof (=1)	-59.5418***
	(3.9259)
Corrugated galvanized sheet roof (=1)	14.3143**
	(5.3249)
Palm or straw roof (=1)	-119.6933***
	(5.1455)
Wooden roof (=1)	-55.1338***
	(4.2080)
Terrado with beams roof (=1)	-32.4097***
	(4.5349)
Roof tile (=1)	-40.9097***
	(4.2457)
Concrete slab roof (=1)	-41.6811***
	(4.0853)
Housing unit floor	
Baseline level: Ground floor	
Cement floor (=1)	-9.2195***
	(1.3464)

Wooden floor	223.0834***
	(1.7970)
Distribution regions	
Baseline level: Bajio	
Baja California (=1)	262.1900***
	(1.3427)
Noroeste (=1)	-32.4921***
	(1.4839)
Norte (=1)	-110.9273***
	(1.9012)
Golfo norte (=1)	51.4053***
	(2.3565)
Centro occidente (=1)	49.0569***
	(2.9292)
Centro sur (=1)	12.1288***
	(3.4546)
Oriente (=1)	-28.9393***
	(3.9869)
Sureste (=1)	-105.5596***
	(4.4963)
Valle de México Norte (=1)	195.5677***
	(5.0618)

Valle de México Centro (=1)	154.4801***
	(5.6569)
Valle de México Sur (=1)	209.6607***
	(6.1809)
Golfo centro (=1)	-41.8164***
	(6.6886)
Golfo oriente (=1)	-18.9470**
	(7.2608)
Peninsular	145.8517***
	(7.8425)
Jalisco	197.9669***
	(8.4190)
Constant	-259.2875***
	(6.3477)
Observations	25,176,536
R^2	0.3953
F	2.612e+05

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Bibliography

Agthe, D. E. and Billings, B. (1987). "Equity , Price Elasticity , and Household Income under Increasing Block Rates for Water". *The American Journal of Economics and Sociology* 46.3, pp. 273–286.

Angel-Urdinola, D. and Wodon, Q. (2007). "Do Utility Subsidies Reach the Poor ? Framework and Evidence for Cape Verde, Sao Tome and Rwanda". *Economics Bulletin* 9.4, pp. 1–7.

Baerenklau, K. A., Schwabe, K. A., and Dinar, A. (2014). "The Residential Water Demand Effect of Increasing Block Rate Water Budgets". *Land Economics* 90.4, pp. 683–699.

Barde, J. and Lehmann, P. (2014). "Distributional effects of water tariff reforms - An empirical study for Lima, Peru". *Water Resources and Economics* 6, pp. 30–57. DOI: 10.1016/j.wre.2014.05.003.

Bigerna, S. and Bollino, C. A. (2016). "Ramsey prices in the Italian electricity market". *Energy Policy* 88, pp. 603–612. DOI: 10.1016/j.enpol.2015.06.037.

Borenstein, S. (2008). "Equity Effects of Increasing-Block Electricity Pricing". Berkeley.

Borenstein, S. (2012). "The Redistributional Impact of Nonlinear Electricity Pricing". *American Economic Journal: Economic Policy* 4.3, pp. 56–90. DOI: http://dx.doi.org/10.1257/pol.4.3.56.

Borenstein, S. (2013). “Effective and Equitable Adoption of Opt-In Residential”. *Review of Industrial Organization* 42, pp. 127–160. DOI: 10.1007/s11151-012-9367-3.

Cardenas, H. and Whittington, D. (2019). “The consequences of increasing block tariffs on the distribution of residential electricity subsidies in Addis Ababa, Ethiopia”. *Energy Policy* 128, pp. 783–795. DOI: 10.1016/j.enpol.2019.01.033.

Centro de Investigación para el Desarrollo (2015). *Es posible reestructurar los subsidios energéticos*. Tech. rep. Mexico city: CIDAC, pp. 1–66.

CONEVAL (2016). *Pobreza en México*.

Cowan, S. (2004). “Utility Regulation and Risk Allocation : The Roles of Marginal Cost Pricing and Futures Markets”. *Journal of Regulatory Economics* 26.1, pp. 23–40.

Dahan, M. and Nisan, U. (2007). “Unintended consequences of increasing block tariffs pricing policy in urban water”. *Water Resources Research* 43.W03402, pp. 1–10. DOI: 10.1029/2005WR004493.

Davis, L. W. (2013). “The Economic Cost of Global Fuel Subsidies”. Cambridge.

Di Bella, G. and Grigoli, F. (2017). “Power it up: Strengthening the electricity sector to improve efficiency and support economic activity”. *Energy Economics* 67, pp. 375–386. DOI: 10.1016/j.eneco.2017.08.019.

Dutta, G. and Mitra, K. (2017). “A literature review on dynamic pricing of electricity”. *Journal of the Operational Research Society* 68.10, pp. 1131–1145. DOI: 10.1057/s41274-016-0149-4.

Espinosa, R. and Rosellón, J. (2017). “Optimal transmission tariff regulation for the Southern Baja-California electricity network system”. *Investigación Económica, UNAM* LXXVI.301, pp. 3–56. DOI: 10.1016/j.inveco.2017.12.001.

Friedman, L. S. (2011). "The importance of marginal cost electricity pricing to the success of greenhouse gas reduction programs". *Energy Policy* 39, pp. 7347–7360. DOI: 10.1016/j.enpol.2011.08.063.

Fuente, D., Gatua, J. G., Ikiara, M., Kabubo-Mariara, J., Mwaura, M., and Whittington, D. (2016). "Water and sanitation service delivery, pricing, and the poor: An empirical estimate of subsidy incidence in Nairobi, Kenya". *Water Resources Research* 52, pp. 4845–4862. DOI: 10.1002/2015WR018375.

Gong, C., Yu, S., Zhu, K., and Hailu, A. (2016). "Evaluating the influence of increasing block tariffs in residential gas sector using agent-based computational economics". *Energy Policy* 92, pp. 334–347. DOI: 10.1016/j.enpol.2016.02.014.

Green, R. (2007). "Nodal pricing of electricity : how much does it cost to get it wrong ?" *Journal of Regulatory Economics* 31, pp. 125–149. DOI: 10.1007/s11149-006-9019-3.

Hancevic, P. and Lopez-Aguilar, J. (2018). "Energy efficiency programs in the context of increasing block tariffs: The case of residential electricity in Mexico". *Munich Personal RePEc Archive* 80093.

Henson, S. (1984). "Electricity Demand Estimates under Increasing-Block Rates". *Southern Economic Journal* 51.1, pp. 147–156.

Hung, M. F. and Chie, B. T. (2017). "The long-run performance of increasing-block pricing in Taiwan's residential electricity sector". *Energy Policy* 109, pp. 782–793. DOI: 10.1016/j.enpol.2017.07.052.

Kejser, A. (2016). "European attitudes to water pricing: Internalizing environmental and resource costs". *Journal of Environmental Management* 183, pp. 453–459. DOI: 10.1016/j.jenvman.2016.08.074.

Komives, K., Johnson, T. M., Halpern, J. D., Aburto, J. L., and Scot, J. R. (2009). "Residential Electricity Subsidies in Mexico Residential Electricity Subsidies in Mexico: Exploring Options for Reform and for Enhancing the Impact on the Poor". Washington, D.C.

Li, L., Yao, Y., Yang, R., and Zhou, K. (2018). "Is it more effective to bring time-of-use pricing into increasing block tariffs ? Evidence from evaluation of residential electricity price policy in Anhui province". *Journal of Cleaner Production* 181, pp. 703–716. DOI: 10.1016/j.jclepro.2018.01.209.

Madureira, N. L. (2014). *Concepts in Energy*. Switzerland: Springer International Publishing, pp. 1–225. DOI: 10.1007/978-3-319-04978-6.

Malko, J. R. and Swensen, P. R. (1989). "Pricing and the Electric Utility Industry". In: *Public Utility Regulation: The Economic and Social Control of Industry*. Ed. by K. Nowotny, D. B. Smith, and H. M. Trebing. Dordrecht: Springer Netherlands, pp. 35–77. DOI: 10.1007/978-94-009-2508-3_4.

Mcrae, S. D. and Wolak, F. A. (2019). "Retail Pricing in Colombia to Support the Efficient Deployment of Distributed Generation and Electric Vehicles".

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, pp. 198–212. DOI: 10.1016/j.jeem.2010.06.003.

Nordhaus, W. D. (2016). "Projections and Uncertainties About Climate Change in an Era of Minimal Climate Policies". Cambridge.

Parry, I., Heine, D., Lis, E., and Li, S. (2014). *Getting Energy Prices Right: From Principle to Practice*. Washington, D.C: International Monetary Fund, pp. 1–199.

Passey, R., Haghdadi, N., Bruce, A., and MacGill, I. (2017). "Designing more cost reflective electricity network tariffs with demand charges". *Energy Policy* 109, pp. 642–649. DOI: 10.1016/j.enpol.2017.07.045.

Ramsey, F. (1927). "A contribution to the theory of taxation". *Economic Journal* 37, pp. 47–61.

Reiss, P. C. and White, M. W. (2005). "Household Electricity Demand , Revisited". *Review of Economic Studies* 72, pp. 853–883. DOI: 10.1111/0034-6527.00354.

Reynaud, A. (2016). "Assessing the impact of full cost recovery of water services on European households". *Water Resources and Economics* 14, pp. 65–78. DOI: 10.1016/j.wre.2016.04.001.

Schoengold, K. and Zilberman, D. (2014). "The economics of tiered pricing and cost functions: Are equity, cost recovery, and economic efficiency compatible goals?" *Water Resources and Economics* 7, pp. 1–18. DOI: 10.1016/j.wre.2014.07.002.

SENER (2017). *Primer análisis sobre los beneficios de la generación limpia distribuida y la eficiencia energética en México*. Tech. rep. Mexico City: Secretaría de Energía, pp. 1 –22.

Shepherd, W. G. (1992). "Ramsey pricing: Its uses and limits". *Utilities Policy* 2.4, pp. 296–298. DOI: 10.1016/0957-1787(92)90007-6.

Stiglitz, J. (2000). *Economics of the Public Sector*. Third edit. W.W. Norton and Company.

Sun, C. and Lin, B. (2013). "Reforming residential electricity tariff in China: Block tariffs pricing approach". *Energy Policy* 60, pp. 741–752. DOI: 10.1016/j.enpol.2013.05.023.

Whittington, D. (1992). "Possible Adverse Effects of Increasing Block Water Tariffs in Developing Countries Source". *Economic Development and Cultural Change* 41.1, pp. 75–87.

Wolak, F. A. (2008). “Public utility pricing and finance”. In: *The New Palgrave Dictionary of Economics*. Ed. by S. N. Durlauf and L. E. Blume. Second edi. London: Palgrave Macmillan, London.