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CIDE

THE IMPACT OF SUBSIDIES OF RESIDENTIAL SECTOR ELECTRICITY TO PHOTOVOLTAIC TECHNOLOGIES ADOPTION

TESINA

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MAESTRO EN ECONOMÍA

PRESENTA

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A mis padres,
a mi hermano
y a mi Estrella Gris.

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Abstract

The Federal Electricity Commission has the responsibility, as the only firm in charge of the distribution of electricity, to improve the investment needed to reach the energy transition's goals in favor of clean sources. The Mexican government has developed a group of programs and funds intending to boost an individual's installation of self-generators of energy, such as solar panels in houses. The main objective of this paper is to show, using Special Regression estimator taken from Dong and Lewbel (2015), that high levels of subsidies that the government spends in electricity, decrease the incentives of households to invest in solar panels. This research presents how the effect of subsidies is adverse to the propensity to install solar panels; it proves that the government is not allowing households to take part in the energy transition.

Keywords: Energy transition, Special Regression, Subsidies, electricity consumption
JEL classification: E62, H23, H31, K32, Q43.

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Chapter 1

Introduction

Household electricity consumption is a critical factor in the energy transition due it is one of the sectors with high demand. Moreover, it has one of the highest rates of growth. In this sense, the Federal Electricity Commission (CFE in Spanish) is in charge of the distribution of electricity to the residential sector. Additionally, it has the complete responsibility to decide the sources of electricity generation. Furthermore, the solar panel market is taking impulse due to research and development worldwide, in this context, CFE will not take advantage of this if subsidies persuade users to avoid investment in solar panels.

The Mexican government wants to explore the area, promoting credits, programs, and assistance to households to invest in solar panels and other efficient technologies. Nevertheless, at the same time, the government is spending three of every one peso that families pay for electricity. The support on electricity prices has the intention of increasing the purchasing power of people who have low or meager incomes; however, the criteria for payments and tariffs do not allow discrimination to favor low-income people. On the contrary, the population sees low cost in electricity, and therefore, they do not see incentives to install solar panels.

In this sense, if the government limits the spending on subsidies on electricity consumption, will the households see the installation of solar panels as a solution to decrease the payment for electricity?

Our hypothesis is uncomplicated: contracting the spending on subsidies of the residential sector will reduce the pressure on public finances, but one will see an increase in demand in photovoltaic technologies, solving part of the pressure CFE has to develop and invest in clean sources of energy.

To reach our goal, we take data from ENCEVI for 2018. Using the methodology of Dong and Lewbel (2015) 'Special Regression,' we could avoid heteroscedasticity and endogeneity problems and determine the direct impact of an increase of price on demand of solar panels. Results provide information about the negative impact of subsidies on the propensity to install solar panels, just like our hypothesis mentioned.

The document structure is as follows: the first part shows the legal framework Mexican authorities have developed to promote clean sources technologies; then, it is reviewed the residential sector structure and some studies about the impact of subsidies on energy production and consumption. Later, methodology from Dong a Lewbel named 'Special Regression' is exposed; likewise, data and statistics are displayed. Next, results are presented, and finally, it is exposed the discussion and conclusions section.

Chapter 2

Legal framework

Since 2015, the Mexican government created the Transition Energy Law (LTE in Spanish). With that, it started the basis to regulate the generation of energy in favor of clean and sustainable sources, reduce emissions caused by the Electricity Industry, and promote competition among productive sectors.

The above is explicit in article 2, fraction V, VI, VII, and VIII, which also includes the co-operation to comply with the General Law on Climate Change (LGCC in Spanish) -this law is in charge of proposing and design programs to preserve and restore de ecologic equilibrium-. In this way, the government, through Energy Secretary (SENER), designs the Transition Strategy to Promote the Use of Clean Technologies and Fuels (ESTRATEGIA in Spanish) to reach the transition into clean sources.

The ESTRATEGIA gets together a multi-disciplinary group to design ideas and projects to achieve the goals established in LTE without sacrifice efficiency in production, consumption, and storage of energy. The ESTRATEGIA recognizes several institutions to take part in developing programs and funds to achieve LTE goals. One of these institutions is *Fideicomiso para el Ahorro de Energía Eléctrica* (FIDE). FIDE is an action plan to improve the energy transition in the industrial and residential sectors. FIDE centers mainly in provide credits and assistance to households and PyMES to adopt more efficient technologies -energetically speaking-, also, the installation of solar panels.

FIDE developed the program titled: *Programa de Mejoramiento Integral Sustentable de Vivienda* (PROGRAMA). This plan has the primary objective of spending reduction from households based on sustainable strategies. PROGRAMA studied the residential sector and found that 27.4% of the country's energy consumption is in households (SIE, 2017). Likewise, the residential sector is a critical sector due to 88.7% of users from SEN come from there (SENER, 2018).

Also, according to estimations from the central plan developed by the government to drive the electricity system *Programa de Desarrollo del Sistema Eléctrico Nacional* (PRODESEN) 2019-2033, the residential consumption electricity will increase by around 3.3% in the next years (measured as average growth rate). Thus, the residential sector is the third sector with the highest rates of growth -only behind Medium-Sized Companies and the Big Industry consumption growth rates-. For the above, focusing the efforts to understand and try to promote the residential sector transition by itself is very important for ecological and economic purposes.

The PROGRAMA raises the next premise: the Mexican government is highly subsidizing the residential sector electricity consumption, for this reason, if programs were developed to favor the installation of clean energy sources in homes, we must wait for a double positive effect: i) on the one hand, employing clean technologies to self-consumption will impulse a reduction in contamination levels through time, and on the other hand; ii) less demand for electricity provided by CFE will imply lower payment for electricity concept for households, and then, the government may spend less for electricity subsidies concept, and it will see an improvement in public finances.

Table 2.1 shows the average kilowatt/hour (kWh) prices, which are broken down in cost paid by households and cost paid by the government. Interpretation is evident; for each Mexican peso that households spend in electricity, the government is contributing to three pesos. For that reason, efforts centered on reducing household payments are significant, for each peso households to save, the government could save three. For the above, it is essential to persuade households to invest in self-generating electricity, specifically in solar panels.

Table 2.1: Prices and subsidies in residencial sector in 2018

Tariff	Average price $/kWh	Average subsidy $/kWh	Percentage of subsidy
Domestic 1	1.06	3.18	0.75
1A	1.06	3.18	0.75
1B	1.05	3.19	0.7524
1C	1.14	3.1	0.7311
1D	1.12	3.13	0.7365
1E	1.02	3.22	0.7594
1F	1.05	3.19	0.7524

Source: Retos, Logros y Desafíos. FIDE 2013-2018

So, one could propose the transition to solar panels installation. This kind of technology has several advantages; it does not imply to drain the source nor generating residuals. Thus, together with the eolic energy, solar energy is considered one of the most important clean energy generators. Consequently, the production of electricity through solar panels can bring down contamination levels. Indeed, solar and wind energy are the cleanest sources we must take advantage of (Pasqualino, et al. 2015). Promoting photovoltaic technologies to replace traditional technologies will be beneficial to the environment and health.

PROGRAMA invests in 11 sustainable technologies. Two of them are photovoltaic ones (panels and heaters). Besides, PROGRAMA impulses te substitution of electric devices in favor of more efficient ones. The PROGRAMA goal is to persuade users to change their technologies, decrease the demand for electricity, reduce their electricity consumption -and payments-, and finally, diminish contaminant levels.

At the end of 2018, PROGRAMA has authorized credits to allow the installation of 5,323 different technologies in 2,194 houses. Photovoltaic systems and waterproofing the most demanded type of technology.

The main goal for introducing that set of laws, regimentation, institutions, and regulations is to comply with the global ecological purpose. In 2050, 50% of all the energy produced has to come from clean sources. According to this objective, and to the goal of PROGRAMA, center efforts to introduce solar technologies in the residential electricity market is crucial to achieving that critical goal.

2.1 The solar industry in Mexico

The National Electricity Centre (SEN in Spanish) is divided into nine regions; each region has a Regional Centre whose installed capacity is 70, 053 MegaWatts (MW) in 2018. Going back to the clean energy approach, 23.18% of total energy generates comes from clean sources. Of them, photovoltaic systems are one of the most expansion sources (PRODESEN 20139-2033).

The German Corporation for International Cooperation (GIZ in German) indicates in its document «*Inversión en Energía Solar en México*» that the impulse in photovoltaic technologies comes from investment expectations and it is visible in the activity en long term auctions. It is estimated that all the energy that the Earth receives from the sun in ten days is equivalent to all the energy that could be produced from all fossil sources (Gasca, 2013). For the above, the solar sun becomes an energy source that is practically inexhaustible and has a high potential for human use.

From an international perspective, a study elaborated for PROMEXICO in 2017 shows that photovoltaic technologies are the third clean source most important -in electricity generation terms-, only superated by hydroelectric and eolic technologies.

Throughout the last years, notable advances in reception, generation, and electricity storage have been developed. Mainly, there are two kinds of photovoltaic technologies: i) photothermic photovoltaic systems and; ii) photovoltaic systems. The first one is associated with solar heaters, transforming solar energy into hot and used to heat and evaporate water. The second ones correspond with solar panels, transforming solar energy into electricity.

Solar panels have experienced a scientific advance in their features and particularly in their costs. For example, in 2014, Hancevic et al. (2014) show that an average Mexican household would wait 15 years to see the investment returns, but, in 2017, PROMEXICO indicated that the investment return could be visible into two years. Furthermore, it is an estimated useful life of around 20 years for the newest solar panels. So, there exist advances which decrease the costs of installations and can persuade households to install to diminish the cost of electricity.

Finally, it has been proved that 95% of Mexican territory is appropriated to utilize solar energy. The Global Horizontal Irradiance (GHI) -Index to measure the radiation received from the sun in a horizontal surface- indicates Mexico has an average higher than $5 \, \frac{kWh}{m^2}$, signifying that solar radiation could be utilized at maximum in almost all the nation.

2.2 The residential sector

According to Energetical Information System (*Sistema de Información Energética*, SIE in Spanish), in 2017, 27.4% of electricity consumption comes from the residential sector. Also, the residential sector has the third-highest growth rate, whereby, if there is no intervention from the government, there will be unnecessary pressure over public finances and environmental objectives. So, restructuring of tariff schemes is needed to incentivize households to reduce the demand to the SEN in the median and long run.

The tariffs scheme in Mexico is characterized for contains a high subsidy in it. This is done to reduce the charge of payment in households and allow low-income people to reach consumption levels that they could pay with higher electricity tariffs. Moreover, it allows the government to keep the kWh prices fixed.

It is known that fossil sources to generate energy -and electricity- are so sensitive to exogenous shocks. For that, when the electricity industry faces an increase in the electricity generation's cost, the government participates with its subsidies to avoid households perceiving these price variations. Nonetheless, using this fiscal tool without establishing an objective population will produce a debt circle that could perform a more significant wealth loss (Awan et al. 2019).

Chapter 3

Theorical framework

There are several types of research within the economic perspective; the vast majority try to analyze the effects of subsidies on economic agents' decisions. In this section, we show some researches and pretend to establish the relationship between subsidies and economic performance.

Di Bella et al. (2015) study the subsidies scheme in Latin America and the Caribbean (LAC) on the energy system. They found that approximately, the governments spend 1.8% of their Gross Domestic Product (GDP) in subsidies: 1% on fossil fuel and 0.8% in electricity. The problem is that those subsidies are not well focused, and those countries have avoidable pressure in their public finances and their environments -due to the excess of fuel using-.

Moreover, the authors emphasize the low authority capacity to charge the price of electricity to households. LAC tariff schemes have the problem of 'no payment,' where, despite paying an artificially lower price for electricity, there are households who do not pay, and the authorities have a little action to charge fines and surcharges. A subsidizing scheme must consider all the shock that the electricity industry and the economy could have. Another problem the authors see in LAC subsidize schemes is that the reduction in electricity. while it is true that low-income people can reach more goods and services, in general, high-income people take advantage of this price reduction in higher proportions.

Furthermore, Ibarrán, M. (2013) analyzes the effects of subsidies on fuels on the quality of air in the ZMVM. Specifically, she proposes that a reduction in subsidies will detonate higher health in its inhabitants. She employs a Dynamic General Equilibrium Model to simulate the response on economic performance after a diminution in the subsidy. She suggests a gradual reduction of subsidy and sees that the economy will have a negative impact in the short run. Economic growth rates will be lower in the first 12 years -because of the fall in consumption-, but later, the investment -because of the surge of new technologies- will boost economic performance and finally will impulse society's welfare. According to the author, after 20 years, only the households with the highest income will not see an improvement in their income.

Badani and Jessoe (2013) study the relationship between subsidies to electricity on water over-exploitation of springs and agricultural production in India. They found out with panel data that subsidies increase the demand for water and agricultural production and even promoting the hydric over-exploitation.

Ávila et al. (2005) do similar research for the Mexican case. They study the subsidies in 09-Tariff -pumping water for agricultural irrigation- on over-exploitation on aquifers. Not surprisingly, authors found that reduction in subsidies on tariff 09 will mitigate the over-exploitation of aquifers. Further, they found an elasticity of -15%; in other words, when the implicit price of electricity rises 100%, the extraction of water decrease 15%. With that, the authors conclude that increasing the prices of electricity tariffs will serve as an economic policy to benefit the environment reducing the exploitation pressure in aquifers..

About technologies' substitution, Zhang et al. (2014) provide fundamental data about the importance of economic policies into the transition to new technologies. The authors evaluate the incentives proposed for the United Stated to transition to electric vehicles. Some of these incentives were credits promotion, diminishing in taxes, amounts, number of taxes; additionally, they will enjoy exclusive rails to non-contaminant vehicles and even free parking. They discover that even with the shock of the real state crisis of 2008 and 2009, the electric vehicles market shows a positive trend in sales. Furthermore, the share of electric vehicles over the total increased even in 2008 and 2009. With these discoveries, authors proved that even with an economic crisis, well-structured policies could put up with external shocks and can reach its purposes. As a brief conclusion, by creating incentives -among them, subsidies- it is possible to bring a significative break in the vehicles industry in favor of low-emission and zero-emission cars.

Talking about Mexico, some studies are trying to see how much time a household require to recover its investment in solar panels. Hancevic et al. (2017) show that, in 2014, an average Mexican household must wait 15 years as a minimum to recover its investment in solar panels. It can be a problem because not every family tends to value the future enough to spend with this slow yield. However, if the price of electricity increases -through subsidy reduction- then the time to recover the investment will decrease. More than one family will reconsider investing in solar panels instead of continuing paying 'high' prices of electricity.

In this sense, this paper contributes to the investigation providing evidence of the impact of subsidies in the solar panel market. In 2018, according to the International Energy Agency (2018), the Mexican government spent around 13.5 billion dollars. This amount affects the fiscal deficit the government has and compromises its action margins to future administrations. Therefore, the government has a high margin to action to improve a diminish in subsidies, spending more in credits to acquire clean technologies and changing the structure of generation of electricity in the residential sector.

Chapter 4

Metodology and Data

To reach the goal of this research, we use data taken from the National Survey on Energy Consumption in Private Households (ENCEVI in Spanish) 2018. Likewise, we get together information about the tariff scheme on the residential sector written in the CFE's ACUERDO 123/2017.

Table 4.1 shows the tariff scheme. It is shown how the way in how the price is determined is related to three variables:

1. The average temperature of the location
2. The level of consumption of the household,
3. The station of the year (summer or no summer period)

Table 4.1: Tariffs Scheme CFE 2018

Tariff	Summertime	No Summertime	Summertime	No Summertime
1	0.793	0.793	First 75 kWh	NA
AvTS.	0.956	0.956	Next 65 kWh	NA
	2.802	2.802	Additional kWh	NA
1-A	0.697	0.793	First 100 kWh	First 75 kWh
AvTS: 25	0.822	0.956	Siguientes 50	Siguientes 75 kWh

Table 4.1 (continuation)

Tariff	Summertime	No Summertime	Summertime	No Summertime
	2.802	2.802	Additional kWh	Additional kWh
1-B	0.697	0.793	First 125 kWh	First 75 kWh
AvTS:28	0.822	0.956	Next 100 kWh	Next 100 kWh
	2.802	2.802	Additional kWh	Additional kWh
1-C	0.697	0.793	First 150 kWh	First 75 kWh
AvTS: 30	0.822	0.956	Next 150 kWh	Next 100 kWh
	1.05	NA	Next 150 kWh	NA
	2.802	2.802	Additional kWh	Additional kWh
1-D	0.697	0.793	First 75 kWh	First 75 kWh
AvTS: 31	0.822	0.956	Next 225 kWh	Next 100 kWh
	1.05	NA	Next 200 kWh	NA
	2.802	2.802	Additional kWh	Additional kWh
1-E	0.583	0.793	First 300 kWh	First 75 kWh
AvTS: 32	0.726	0.956	Next 450 kWh	Next 125 kWh
	0.948	NA	Next 150 kWh	NA
	2.802	2.802	Additional kWh	Additional kWh
1-F	0.583	0.793	First 300	First 75 kWh
AvTS: 33	0.726	0.956	Next 900	Next 125 kWh
	1.768	NA	Next 1300	NA
	2.802	2.802	Additional kWh	Additional kWh

Source: Acuerdo 123/2017

ACUERDO POR EL QUE SE AUTORIZAN LAS TARIFAS FINALES DE ENERGÍA ELÉCTRICA DEL SUMINISTRO BÁSICO A USUARIOS DOMÉSTICOS

AvTS: Average Temperature in Summer in the location

It is necessary to highlight that when there is no summertime, the tariff scheme only considers three consumption levels. The first one denominated 'Basic Consumption' has a limit of around 75 kWh per month. Then, once a house has superimposed this barrier, it enters the denominated 'Intermediate Consumption,' and just as seen in the Table 4.1, for each kWh consumed in Intermediate Consumption, the households have to pay higher prices than Basic Consumption had. Intermediate consumption has a margin of about 75-125 kWh, but, once the house has wasted more than 75 kWh and 75-125 kWh additionally, that house enters in 'excess consumption.' For each kWh consumed in excess consumption, households have to pay the higher prices from these additional kWh.

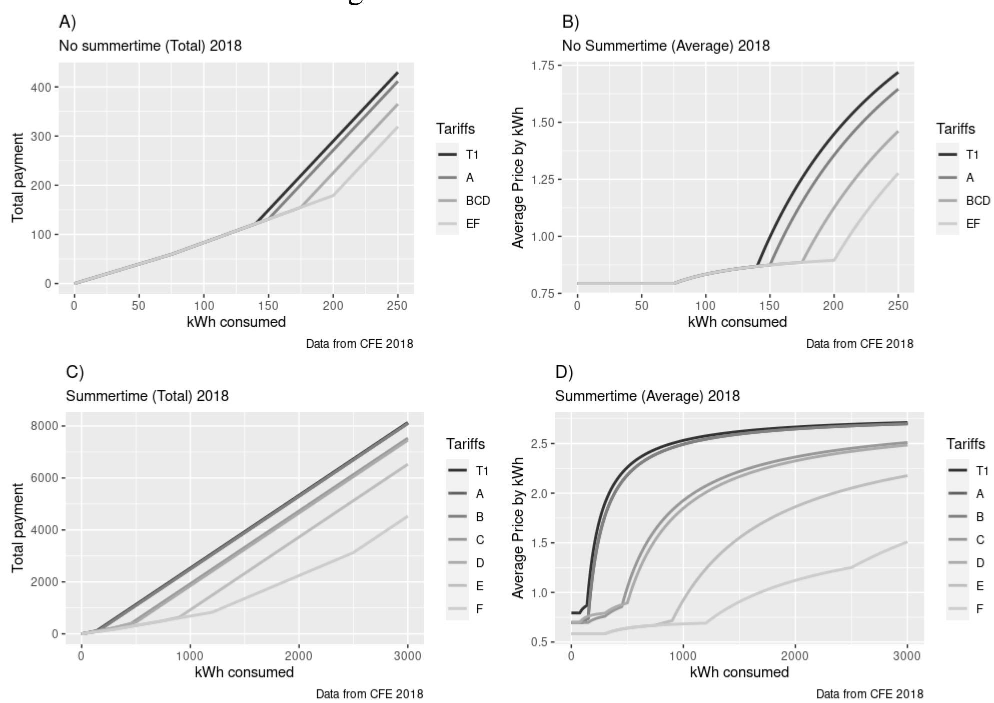
For each kWh spent in Intermediate Consumption, a household must pay 0.956 pesos, but, for each KhW consumed in Excess Consumption, a house have to pay 2.802 pesos, this is, almost 200% high.

Similarly, in the summertime happen the same, but now, there are tariffs where there are four segments of consumption. What happens is that 'Intermediate Consumption' was divided into 'Intermediate Low-Consumption' and 'Intermediate High-Consumption,' allowing more consumption before enters in 'Excess Consumption,' but it follows the same structure.

Figure 4.1 explains in a better way, the behavior of the tariffs according to the level of consumption made. Panel A shows the accumulated payment one must pay wherever be the consumption of electricity in the no-summertime. Remarkably, tariffs exhibit a similar trend in the first levels of consumption -Basic Consumption-, however, once their respective thresholds are overtaken, their slopes take a different value and begin to diverge between them until reaching the same slope in 'Excess Consumption' zone. This behavior results even more evident if we take a look at average prices. Panel B presents the average price one must pay according to different levels of consumption outside the summertime. What one can see is that when the consumption level enters in 'Excess Consumption' zone, the average price per kWh begins to overgrow.

Panel C shows the cumulative payment one must do in the summertime, and Panel D exhibits the average prices households face in summertime. Surprisingly, in Panel D we can see how, due to 1, 1-A, and 1-B tariffs has the shortest thresholds, average prices per kWh increases substantially implying that population living under 1, 1-A, and 1-B tariffs spend more in electricity even if they had the same level consumption than 1-D, 1-E and 1-F tariffs. For the above, one could wait to see a higher propensity to install solar panels in these tariffs.

Figure 4.1: Tariffs simulation



Source: own elaboration with data from CFE 2018

Table 4.2 shows the house distribution per tariff. Before seeing it, we face an irregular problem; almost 45% of the individuals could not recognize the tariff they are inscribed. This problem could generate bias through self-selection errors and the loss of the data. It is assumed that these households who did not mention their tariffs belong to the same tariff where the majority of the State belongs to avoid the loss of information. With that correction, we must use all the observations and avoid self-selection and without losing data. We agree with the idea of bias caused by measurement error; nevertheless, Special Regression -discussed in the next section-helps to correct the endogeneity from our model.

We could appreciate how 46.14% of all households in the sample said they either did not know their tariffs or did not answer anything. The first column in Table 4.2 presents the reported tariffs. It is visible how the vast majority is inscribed in tariff 1 with 32.7%, followed by households in 1-C tariff with 5.5% of households. The second column indicates the 'corrected' sample, newly, tariff 1 has the majority of the households inscribed in it. Almost 40% of all the households belong to tariff 1, followed closer by tariff 1-D with nearly 25% of households. The fact that four of each ten households belong to 1 tariff reflects the degree of exposure of about 40

Table 4.2: Users by tariff scheme in 2018

Tariff	Percentage of households	Corrected percentage
Unreported	13.02	...
02	0.40	0.74
01	32.76	39.99
1-A	3.72	14.91
1-B	5.07	6.17
1-C	5.52	8.21
1-D	2.06	24.94
1-E	1.88	3.14
1-F	2.19	2.62
DAC	0.22	0.41
Do not know	33.12	...
N	33,162,148	26,204,118

Source: own elaboration with data from CFE 2018

The survey also gives information about the self-generation of electricity. According to the ENCEVI, in 2018, only 0.19% of all households have any electricity self-generator, and only

0.14% have installed solar panels.

Table 4.3 displays the distribution of alternative self-generation of electricity technologies. As it was brought forward above, 75% of these alternative technologies are solar panels, 75% of any house with a self-generator of electricity technology is concerning to solar panels. Additionally, 50% of houses where were installed any other technology comes from tariff 1. This result is harmonious with our hypothesis, because of this tariff has the lowest thresholds to consume, they are more exposed to higher prices, and as we can see, they are more prone to install solar panels.

Table 4.3: Alternative technologies by tariff scheme

Tariff	Solar Panel	Generating Plant	Another source	Total
1	35.644	14.851	0.990	51.485
1-A	5.941	0.990	0.990	7.921
1-B	0.000	3.960	0.000	3.960
1-C	4.950	0.000	0.000	4.950
1-D	23.762	2.970	0.990	27.723
1-E	1.980	0.000	0.000	1.980
1-F	1.980	0.000	0.000	1.980
Total	74.257	22.772	2.970	100.000

Source: own elaboration with data from CFE 2018

By last, ENCEVI also produces information about electricity consumption in houses. From the tariffs schemes, -the corrected tariffs for families belong, and the payments the families did last month- one can determine who are in the 'Excess Consumption' zone and who is not. These results are revealed in Table 4.4. It is important to highlight that the households that belong to tariffs 1 and 1-A are the most susceptible to staying in 'Excess Consumption Zone' (ECZ). Moreover, we could appreciate that these tariffs experience an increment of around 200% of the additional kWh consumed.

In the low part of the Table, we could found the relationship between belonging to an ECZ and the solar panel holding at home. Here, we could say that only 0.08% of houses with solar panels are in ECZ. In effect, there is a positive correlation - but close to zero- between prices and propensity to install photovoltaic technologies. However, we must be alert because of the impact of the causality reverse effect. We must pay attention to houses not belonging to ECZ and with panel holding because they might install their solar panels to decrease their level of consumption and finally ubicate themselves outside ECZ. However, even if they are consuming less electricity from the CFE system, they are actually consuming more electricity, but their photovoltaic systems support them.

Table 4.4: Users by level consumption and tariffs increments 2018

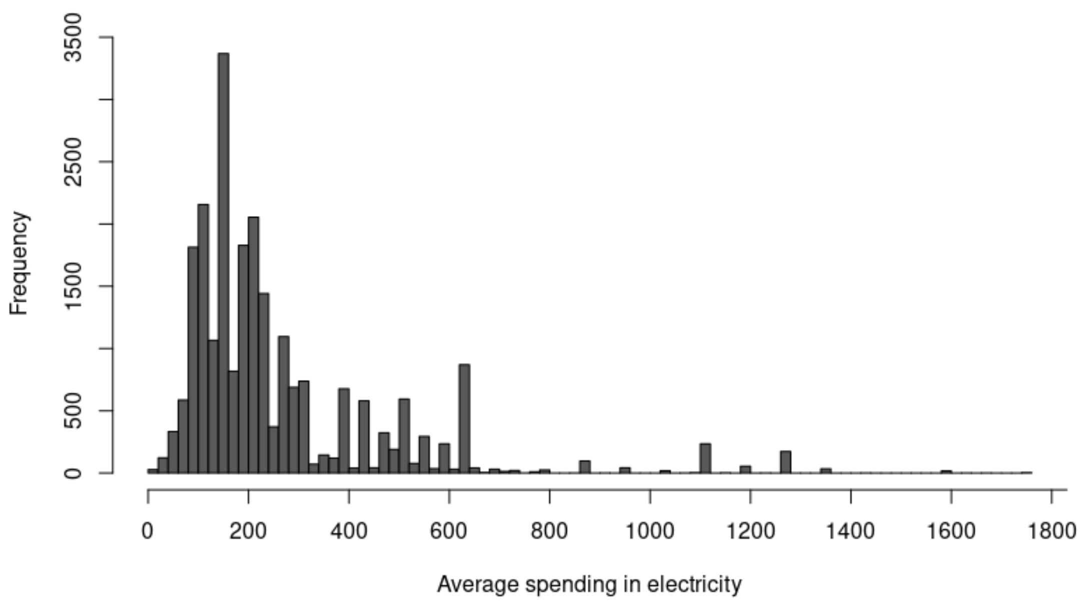
Tariff	Intermediate Price	Excess Price	Increment	No ECZ	ECZ
1	0.956	2.802	193.10%	9.0%	31.0%
1-A	0.822	2.802	240.88%	2.2%	12.7%
1-B	0.822	2.802	240.88%	2.2%	3.9%
1-C	0.822	2.802	240.88%	4.9%	3.3%
1-D	1.05	2.802	166.86%	16.7%	8.2%
1-E	0.948	2.802	195.57%	2.0%	1.2%
1-F	1.768	2.802	58.48%	2.6%	0%
			Panel installed?		
			No	39.61%	60.23%
N	26,204,118		Yes	0.05%	0.08%

Source: own elaboration with data from CFE 2018

We cannot see the 'real electricity consumption' for those who installed solar panels. However, we can try to correct this another problem of endogeneity through Special Regression discussed in the next section.

Additionally, it is presented the spending distribution in electricity. A histogram is presented to display the last payment households did for the electricity concept, Figure 4.2 shows the first 95 centiles on electricity spending -this is to avoid outliers-. Remarkably, the vast majority of households pay between 200 and 400 pesos. The average payment households did for the electricity concept is 318.14 pesos.

Figure 4.2: Electricity spending distribution in 2018



Source: own elaboration with data from CFE 2018

4.1 Methodology

With the propose to obtain the causal relationship between electricity prices and the propensity to install a solar panel, we propose the binary choice model:

$$P(Y_i = 1|ECZ_i, X) = \phi(\alpha ECZ_i + \beta X), \tag{4.1}$$

where Y_i is the variable of interest and indicates if the i household has installed a solar panel, ECZ_i is another dichotomous variable and provides information if the i household belongs to ECZ or not. Finally, X_i is a vector of covariates to reach a better adjustment.

$$Y_i = \begin{cases} 1 \quad if \quad Household\, has\, installed\, solar\, panels \\ 0 \quad if \quad Household\, has\, not\, installed\, solar\, panels \end{cases} \tag{4.2}$$

$$ECZ_i = \begin{cases} 1 \quad if \quad Household\, is\, in\, Excess\, Consumption\, Zone \\ 0 \quad if \quad Household\, is\, not\, in\, Excess\, Consumption\, Zone \end{cases} \tag{4.3}$$

Previously, it was commented that enters in ECZ implies an increase of around 200% in additional kWh consumed price. However, variable ECZ_i may have problems of endogeneity -reverse causality and measurement error-.

Reverse causality can apply because houses, where a solar panel is installed, are not reporting their real consumption; instead, they are reporting only the consumption provided by CFE. In this case, households where $Y_i = 1$ will tend to notify lower probabilities to stay in ECZ. Measurement error applies in two ways. The first one, as discussed before, it was assumed that households who did not recognize their tariffs were, in fact, in the same tariff that the majority of households belong in the same State are. The second way of measurement error effect is the existence of municipality agreements with CFE to allow it to charge the costs of public electricity; approximately, it is charged the 10% of the house consumption. That 10% -and 16% regarding taxes- were removed to evade as much as is possible the measurement error.

Notwithstanding, we must consider endogeneity to provide unbiased estimators. The nature of our variables -both binary- requires a methodology that allows heteroscedasticity in error. Some proposals are probit, logit, instrumented probit, and control function models (Arendt and Holm, 2006; Freedman and Sekhon, 2010).

The first suggestion to correct the endogeneity is the inclusion of, as in lineal models, a vector of instruments. Rivers and Voung (1988) and Smith and Blundell (1985) quoted in Adkins (2008) shows that when we face the endogeneity problem, two stages probit will offer consistent estimator but no efficient ones. Freedman and Sekhon (2010) found out something similar, and even they prove that two stages of non-linear models provide a higher bias in estimators. For that, we agree that Instrumented Probit is not an attractive methodology to address the research.

Ebbes et al. (2016) propose a variation in instrumented methods. They mention that the inclusion of the error of the first stage as a regressor on the second stage, the bias caused by endogeneity, will be corrected -that methodology is called Control Function-. The central concept of Control Function is: if the error is correlated with regressors, adding the error to the first regression will capture these relations, and estimators will be unbiased. However, the authors highlight that this only works when the endogenous variable is continuous. Considering our endogenous variable is not continuous, we may expect to generate heteroscedasticity of residuals. In this sense, Control Function cannot address

Dong and Lewbel (2015) go further and design a new method denominated 'Special Regression.' The authors indicate that the main idea of the Special Regression is the instrumentation of a latent variable. Through a method named 'Special Regressor,' the endogeneity could be avoided and, further, it allows heteroscedasticity on residuals. As we explore later, we use the head of household age as our 'Special Regressor.'

4.2 Special Regression

Dong and Lewbel (2015) comment that when one faces endogenous regressors, both Instrumented Probit and Control Function cannot report efficient estimators. Therefore, they propose to instrument the latent variable through a Special Regressor. This new variable (V) must be considered as 'Special Regressor' and must comply with three properties:

1. Additivity in V and the model error ϵ. Namely, V has to have the form of $y^* = X'\beta + V + \epsilon$;
2. Conditional Independence between V and ϵ;
3. V must be continuously distributed and to have longe support. This assumption can be relaxed.

In this way, the estimation of the model is:

$$D = I(X'\beta + V + \epsilon \geq 0) \tag{4.4}$$

The authors demonstrate that if our Special Regressor is a good instrument, our estimators will have less bias compared with traditional methodologies.

To estimate that model, one must follow the next steps:

1. 1.- Let be V_i 'Special Regressor' with a mean equal to 0. Let be S the vector of other instruments Z and exogenous covariates X. Let's get the residuals of $V_i = S_i'\hat{b} + \hat{U}_i$;
2. Defining a non-parametric density estimator: $\hat{f}_i$, such that: $\hat{f}_i = f(\hat{U}_i|\hat{\sigma^2})$ density may be the normal distribution-;
3. For each observation we define: $\hat{T}_i = \frac{D_i - I(V_i \geq 0)}{\hat{f}_i}$;
4. Obtain the coefficients β from Two Stages Less Squares estimator of T over X;

Finally, the Special Regression Model becomes:

$$P(Y_i|ECZ_i) = I(X'B + V + \epsilon > 0) \tag{4.5}$$

As one can see, the main discussion in the Special Regression estimator is the correct choice of the Special Regressor. Following previous studies (Dong y Lewbel, 2015; Limanli, 2017;

Succurro y Damiana, 2018), the age -in this case, the head of the household- will be proposed as Special Regressor. In the next lines, we discuss why the age can comply with the assumptions made for a Special Regressor.

The intuition would say that when an individual gets older, one gets higher economic conditions, and then acquire more decision power related to the house. However, there is the possibility that, when somebody gets even older, the decision power on the home must be not as reliable as when individuals were younger. For the above, the relationship between age and decision to install solar panels is not clear. Wise and Casas (2013) remark that the relation between decision making and age in older people is not positive because people begin to think that older men are losing their capacities. For this reason, they indicate a negative nexus between age and decision making.

Parallel, it is reasonable that new generations experience new beliefs and realities and demonstrate higher environment protection feelings. For this reason, one could expect that new generations will be more worried about the environment, and perhaps, they will be more prone to install solar panels. Otherwise, García (2006) indicates that until today, there is no empiric evidence supporting that idea, indeed, since the ecologic boom in 1960, generations do not show statistically different ecological behavior.

Other studies, such as made by Carangui et al. (2017), specify that age acts as a certainty factor in decision making. For that, age plays a unique role in behavior among different cohorts due to different perspectives in the family members -and heads-. This statement goes according to the studies trying to explain the beneficial impact of governmental and institutional programs to implement an environmental education (Martínez, 2010). From this educational perspective, cohorts exposed to new ecological policies will have a different behavior -environmentally speaking- and for this reason, younger cohorts would be more prone to install solar panels.

However, the relationship between age and prone to install solar panels continues been uncertain. Even if the younger cohorts are more aware of the environment, they may have low power in the family's decision making -or not-.

To contrast those theories, we propose to analyze the correlation between the age of the head of the household and a menu of responses to some questions that ENCEVI made to capture the households' interest in environmental problems. Figure 4.3 shows this exercise. Panel A displays the percentage of the heads of households who nodded perceive several environmental problems. Graph a) exposes the percentage of heads who believe that in the next years, the economy will face a fuel depletion. It is exhibited how younger cohorts believe more in fuel depletion than older cohorts consider. Something similar happens in Graph c), where older cohorts think statistically different to younger cohorts and show lower intentions to spend in solar panel installations. Nonetheless, there is no statistical difference between the share of yes-answers in Plots b) and d), this indicates that different cohorts do not believe that neither consumption habits nor technologies will improve over time.

Following Wise and Casas, one can repeat the exercise without heads of households older than 85 years old -because of the loosing in decision power in households-. These new estimations are displayed in Panel B. Remarkably, Panel B illustrates the no statistical evidence of differences between age and environmental awareness; in other words, younger and older cohorts think similarly in environmental terms.

Solely Plot a) reports statistically different thinking between cohorts, denoting older cohorts think more that fuel will deplete in the next years. However, they have the same intentions to install solar panels and the same speculation about changes in consumption habits and technologies in the future. For the above, one can conclude that the only relation between age and prone to install solar panels is through electricity prices and not through other ways as environmental awareness.

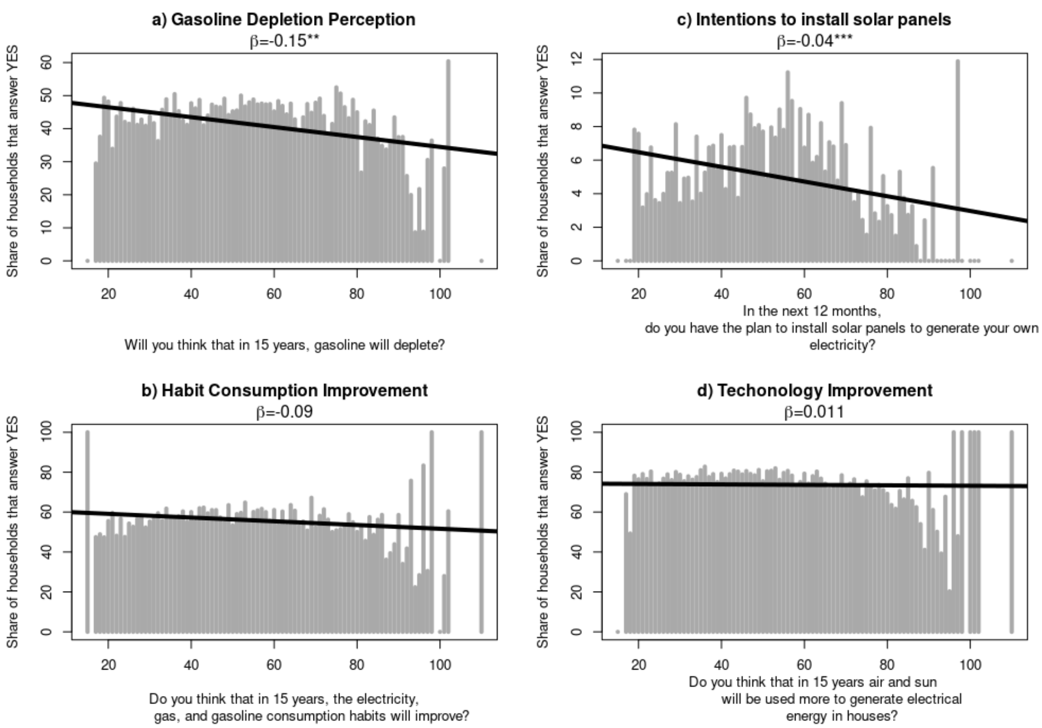
However, from another point of view, one could believe that intentions to install a solar panel is addressing through another route: income. In this case, we must expect that those who possess higher income have more probability of owning solar panels. In this case, one must demonstrate that there is neither relation between age-income nor income-solar panel holding.

To refuse the before-mentioned case, we could regress the panel holding variable with different income, due to the difficult to attach income levels to households, socioeconomic status is proposed as income proxy. Table 4.5 exhibits the results. We could notice that those who have higher income levels -high socioeconomic status- possess higher probabilities of owning a panel. Furthermore, Panel B shows the Probit regressions of being a member of the high socioeconomic status and household's age. When we do not include any control variable, statistically significant coefficients are reported, suggesting that age impacts in income proxy and, through this channel, age affects indirectly solar panels installations.

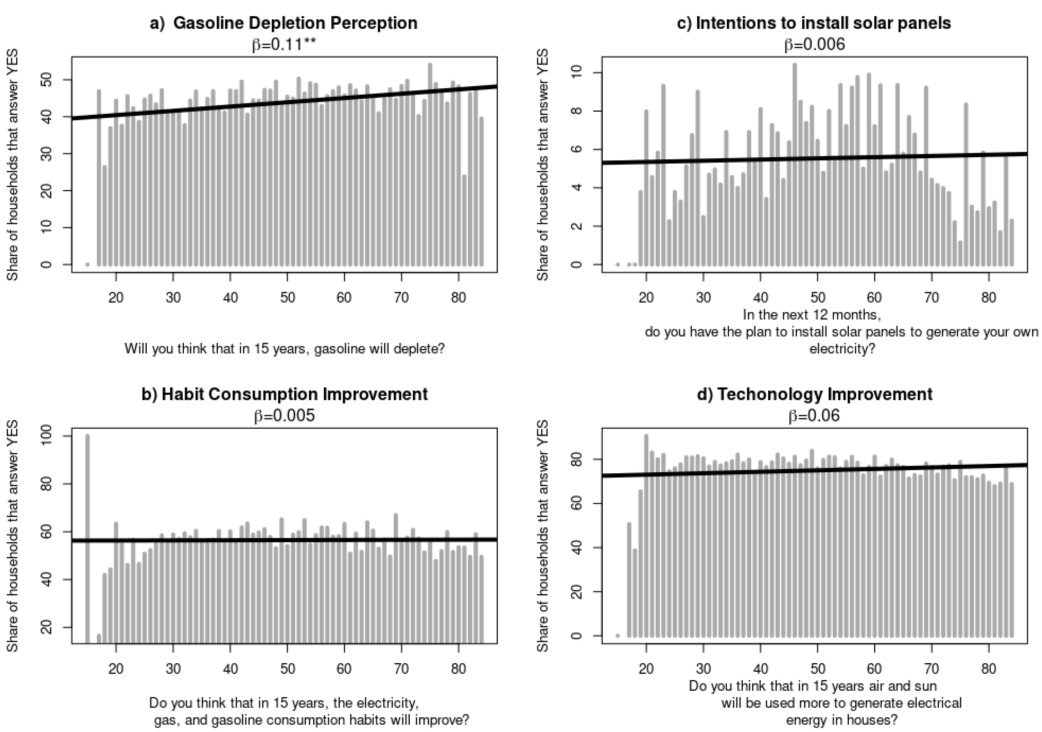
We could argue that the head of the household's age is not the only one who earns money for the family. The second row in Panel B reveals the relation of age-high socioeconomic status when controlled by the number of members in the home. Impressively, results manifest how age is still impacting the income proxy and therefore affecting indirectly in solar panel installations. Age can be a proxy of human capital. Indeed, it contains all the personal investment one can make through life. For that, many variables affect our age and decisions; one of the most important is education. If we take the maximum degree of studies as a proxy of education -third row-, we recognize how age is not addressing income, instead, education and the number of members still doing it. Finally, if we add fixed effects at UPM (Primary Sampling Unit, provided by INEGI), we still observing no relation within age and income levels. In this sense, age has no linear relation with income levels.

Figure 4.3: Correlation Age-Environmental Awareness

Panel A

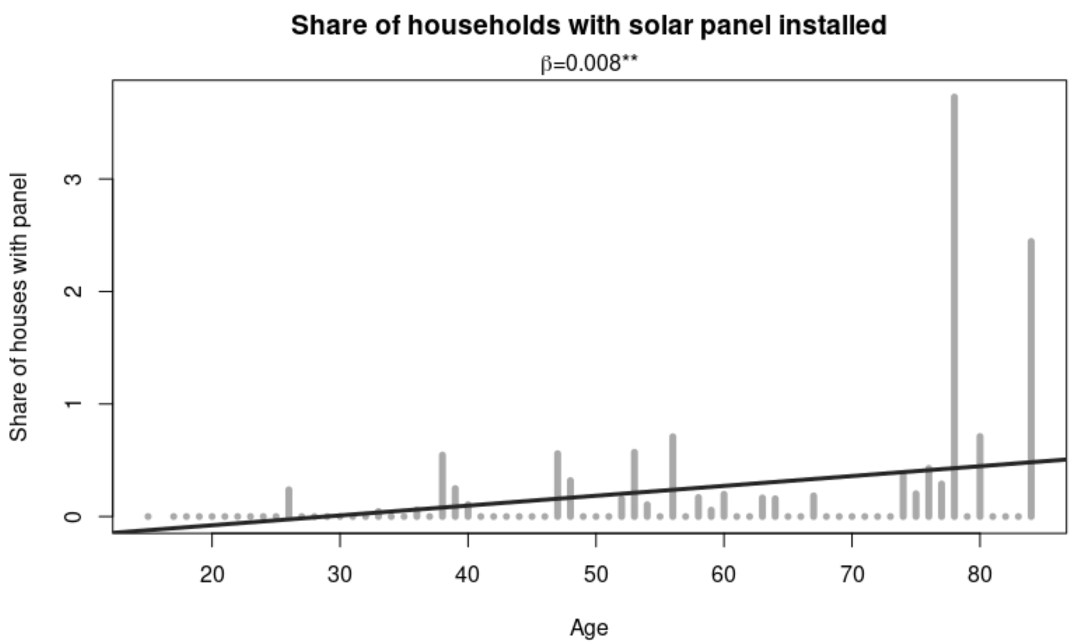


Panel B



Source: own elaboration with data from ENCEVI 2018

Figure 4.4: Relation Age-Solar Panel Holding 2018



Source: own elaboration with data from ENCEVI 2018

Indeed, Figure 4.4 explores the correlation age-solar panel installed. The share of persons in the same age with solar panels is increasing according to age. With this, we could affirm age will work as a Special Regressor, due to it only affects the propensity to install solar panels and no through other ways such as environmental awareness.

Finally, we must prove that age is a variable with extended support and continuos. Even though age belongs between 15 to 85 years, this variable is discrete, -age has limited support- Dong and Lewbel express clearly in the development of their methodology that this assumption is not as necessary as the first ones, so that, we could use the age as Special Regressor, but we must take aware of this when we interpret the results.

Table 4.5: Age as Special Regressor

Panel A: OLS estimates	Variable of interest: Panel Holding	
Socioeconomic Status Ref: Low Status	Lower Middle:	-0.0012 (0.0007)
	Upper Middle:	-0.0007 (0.0008)
	High Status:	0.0024* (0.0011)
High Socioeconomic Status		0.00332*** (0.0009)
Panel B: Probit estimates	**Variable of interest: High Socioeconomic Status**	
.	HH's Age	-0.0054*** (0.0004)
Household members (HM)	HH's Age	-0.0078*** (0.0143)
HM+ Maximum degree of studies (MS)	HH's Age	-0.0022 (0.0017)
HM+MS+Fixed Effects UPM	HH's Age	2.32×10^{-15} (1.7×10^{2})

Source: own elaboration with data from ENCEVI 2018

Chapter 5

Results

Before display the results from Special Regression, I would like to explore some traditional methods. Table 5.1 exhibits the results when we use traditional methods. Panel A contains Ordinary Less Square (OLS) results with no correction on endogeneity; Panel B expressed the Probit results and Panel C contains the Instrumental Variable Probit (IV Probit) results.

The variable of interest is if the house has a solar panel installed or not and the regressors are the house reports about being in the 'Excess Consumption Zone' (ECZ) and a group of covariates such as if they have electric devices at home. Besides, control variables -States, Regions (defined by ENCEVI), or Environmental Awareness (if the head of the house is worried about any environmental problem presented above)-, are added to obtain the direct effect of belonging to ECZ on the solar panels holding.

As instruments -for the IV Probit method, I decide to use several electric devices in the house, such as how many mobiles, spotlights, refrigerators, and so on they have; if they have a business shop, among others. The idea is abstract the consumption level through these devices, in this context, the more devices in the home, the more electricity consumption, higher payments that family has to do, and finally, higher propensity to install solar panels.

Every panel of Table 5.1 contains the estimator of its corresponding regression, their standard error (in parentheses), and the Average Margin Effect (AME). The last one could provide more information about the impact of belonging to ECZ on the propensity of having solar panels installed. Panel A shows the estimator from Ordinary Less Square Method, and different controls added. It reveals no evidence of any effect of prices on solar panel holding, even if controlled by States, Regions, or Environmental Awareness, the estimators are not statistically significant. One could think that the few houses with solar panels cause it due to less than 0.2% of Mexican households have installed one. Thus, it is easy to understand because traditional methodologies will take into account that the expected value is close to zero. To avoid this issue, in the sixth column, we specify a regression only admitting States where at least one house has solar panels. With this, we generate a subsample where the expected value of installing a panel is higher than the full sample is; nevertheless, there remains the same conclusion: no statistical relation between ECZ and propensity to installing solar panels. Despite this, one must remember that the Ordinary Less Squares Method takes into account neither the endogeneity problem nor heteroscedasticity.

To better fit the data, one can propose a probit model because of the nature of our variable of interest. Presented in Panel B, probit results show a similar outcome: there is no statistical evidence of an effect to belong to ECZ on prone to install solar panels. However, one must remember that, again, probit models do not consider the endogeneity problem in their estimations.

Table 5.1: Traditional Methods Estimates

	Variable of interest: Solar Panel Holding					
PANEL A						
O.L.S. Estimates						
	(1)	(2)	(3)	(4)	(5)	(6)
ECZ	-0.000274	-0.133	-0.138	-0.157	-0.159	-0.146
	(0.000541)	(0.108)	(0.111)	(0.123)	(0.126)	(0.117)
PANEL B						
Probit Estimates						
	(7)	(8)	(9)	(10)	(11)	(12)
ECZ	-0.0633	-0.139	-0.147	-0.180	-0.159	-0.146
	(0.101)	(0.109)	(0.112)	(0.125)	(0.126)	(0.117)
AME	-0.00033	-0.00072	-0.00076	-0.00142	-0.00144	-0.00133
PANEL C						
Instrumented Probit Estimates (IVProbit)						
	(13)	(14)	(15)	(16)	(17)	(18)
ECZ	0.255	0.745***	0.791***	0.909***	0.875***	0.519
	(0.429)	(0.224)	(0.234)	(0.249)	(0.259)	(0.370)
AME	-0.00039	-0.00079	-0.00081	-0.00116	-0.00133	-0.0014
Instruments						
Devices	One	Yes	Yes	Yes	Yes	Yes
Controls						
Regions	No	No	Yes	No	No	No
State	No	No	No	Yes	Yes	No
Environmental awareness	No	No	No	No	Yes	Yes

Standard errors in parenthesis

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Source: own elaboration with data from ENCEVI 2018

Panel C presents the IV Probit results. If we omit the recommendations of several authors who mention that IV Probit does not correct the dichotomous variables' bias, one could believe these outcomes are not biased. Indeed, we could see positive and significant estimators in the majority of estimators. Notwithstanding, if we take a look at the AME estimator, we can see negative effects. Therefore, it suggests a biased problem, again, generated by the lousy specification of the model. Furthermore, when we regress with only States with at least one solar panel installed, the regressor is not significant. We cannot conclude any about the impact of ECZ on panel holding.

To sum up, there could be no evidence that increasing the average price of electricity households move to self-generators to electricity. Nevertheless, we know that we need to address the endogeneity problem to have more efficient estimators. Thus, we must use other methods as Special Regression discussed above. Table 5.2 has Special Regression outcomes. We cannot reject our hypothesis. Indeed, belonging to ECZ impulses that households move to photovoltaic tech installations.

If we take a look at the Average Margin Effect, it is distinguished that an increment in electricity price foments between 0.0006 and 0.0024 percentage points new solar panels installed. We know that only 0.14% of households said they have solar panels so that increasing prices -because households enter in ECZ- means an increment in solar panel installations between 0.24% and 2.4%.

Table 5.2: Special Regression Estimates

	Variable of Interest: Panel Holding					
PANEL A						
Special Regressions						
	(1)	(2)	(3)	(4)	(5)	(6)
ECZ	12.44***	20.94***	10.29***	26.31***	19.73***	8.38***
	(2.508)	(3.279)	(1.933)	(2.852)	(2.702)	(2.030)
AME	0.00066	0.00244	0.00112	0.00106	0.00112	0.00135
Instruments						
Devices	One	Yes	Yes	Yes	Yes	Yes
Controls						
Regions	No	No	Yes	No	No	No
State	No	No	No	Yes	Yes	No
Environmental awareness	No	No	No	No	Yes	Yes

Standard errors in parenthesis

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Source: own elaboration with data from ENCEVI 2018

While it is true that we found a positive, unbiased relationship between our variable of interest, we must point out that these increments are occasioned by an increase of around 200% in kWh prices. In other words, when families observe an increase in prices -due to higher prices in excess kWh consumed-, on average, we must see an increment in the demand of solar panels on around 0.24-2.4%.

These outcomes are so near to zero. Again, we can attribute it to the expected value is so close to zero. Less than 0.2% have installed photovoltaic technologies, even if we reduce the sample into only States with at least one solar panel installed, the effect of ECZ is not higher. The Special Regression corrects the endogeneity problem, but the sample still having very few non-zero elements. Therefore, the effect of prices is practically zero.

One could reduce the sample searching higher expected value of Y_i. However, this clearly will limit the external validity of the study and, also, it reduces the inference power and mainly, expands the non-aleatory factor in the sample. While it is true that Special Regression avoids the endogeneity problem, due to the vast number of households without self-generators of technologies, methods will report coefficients so near to zero. If we had data of all the houses in Mexico, we could enrich the analysis and provide more evidence about price changes impact on installed solar panel decisions.

Chapter 6

Conclusions

The main goal of this research was to prove that increasing electricity prices promote the installation of solar panels. In this context, subsidies are mitigating the action of households taking part in the energy transition demonstrating that the government is not coordinating efforts to bring down electricity generation from fossil sources.

On the one hand, we see a government that is working to reduce the residential sector electricity demand and promoting the installation of energetical efficient devices and self-generators of electricity based on clean sources. However, on the other hand, we see how the government is supporting electricity consumption through subsidies. Consequently, the government is not giving enough incentives to help households to make the change in their electricity system.

One can confirm that the government is looking for a reduction in the demand for electricity made by the residential sector. It is notable through the programs, funds, laws, and projects the government design. However, the electricity price is so low that the investment in solar panels is not attractive for the vast majority of the population. Only 0.14% of households in Mexico have improved this change. If we take into account the discount rate from households, we must recognize that increasing electricity prices will reduce the time to return the investment, and more than one head of the households will think to install an alternate source of electricity.

This document provides evidence about how prices impact the decision to install a solar panel. We found out that the increment in the additional kWh consumed prices promote the installation of solar panels up to 2.4

However, we face a limitation. The solar panel market in Mexico is still not so developed. Although solar technologies are taking more strength, in Mexico is still being no developed. The above is seen in the only 0.14% of households that have installed solar technologies. As solar technologies develop and the Mexican market opens to these kinds of technologies, more installations will be reported. Then, there will be more evidence to help to avoid the case of expected value near to zero. Additionally, future researchers have to recognize the endogeneity problem and address it through Special Regression or another specification of the model.

Special Regression helps to correct the biased estimators and provides a positive effect between increment in prices and the propensity to install solar panels. Nevertheless, the estimated impact is so close to zero in comparison with the 200% of increment in prices for each kWh additional consumed. For the above, one could suggest that the policy of reducing subsidies cannot be appropriate to 'force' individuals to install solar panels.

Of course, the proposal has to be subject to economic, political, and social debate. One could argue that the increment of 200% in prices to get 'only' 2.4% more installed panels is not a risk that somebody would take. Moreover, others could claim that lowering subsidies in electricity will affect low-income households, reducing over more, their consumption levels, and consequently, lowering their welfare.

Against those arguments, we must remember the funds, policies, and programs that the government is promoting. In response to the subsidies reduction, high-income households may consider solar panel installation to avoid paying higher tariffs. Others may prefer to reduce their electricity consumption, but others simply will not. With the first households -families who make energy transition- the government will save money that was previously wasted in subsidies. With these additional earnings, the government can impulse even more programs to help households who cannot change their consumption patterns. Devices with low consumption must be provided through government credits or even design a special tariff to help low-income households to reach the energy transition to more efficient devices or self-generators of electricity. With these changes, wealth loss will be minimum and, contrarily, in the long run, contamination levels must decrease, payments made by households will decline, and the government will spend lower amounts in electricity subsidies.

In this context, as discussed above, it will be interesting to research how the households will react to an increment in electricity prices. Future researchers must consider people who do not pay for electricity because they stole it from the free wires and any other behavior that may present with the new tariffs. Additionally, one can study another kind of subsidy to solar panel taxes to decrease costs and become more attractive to households, even if they pay low electricity prices. Notwithstanding, the most important thing is to see how the government will use its tools -in this case, fiscal policy- to push the economy into green technologies way. Alternatively, if the government decides still promoting untargeted subsidies, look for other strategies to persuade households, firms, and the government itself to change the trend of electricity consumption and spending.

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