Elasticities of Residential Electricity Demand in Chile *

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Abstract

Since the early 90s, the electricity demand in Chile has been steadily growing, first at an average rate of 8% from 1990 to 2007 and later at an average of 5.7% between 2008 and 2012. In the past, an increase in demand was followed by increases in supply, even though there were some shortage periods mostly due to droughts. During these shortages, consumers were rationed and there were even some blackout periods for some types of consumers.

In this context of growing demand and stochastic energy supply in Chile, it becomes necessary to fully understand the determinants of the demand of electricity for household use- price elasticity in particular- in order to reduce possible energy deficits through flexible pricing mechanisms. This paper estimates the demand for residential electricity using data from the National Survey of Socioeconomic Characterization (CASEN) 2006, being innovative over previous studies by using disaggregated data per household. The results are consistent with other results in the literature, showing a price elasticity between -0.38 and -0.40 for residential consumption, cross- elasticity between 0.14 and 0.16 with respect to the price of liquefied gas, and an income elasticity of between 0.11 and 0.12, depending on whether it was evaluated on the median or mean of the independent variables. In conclusion, the results show the feasibility of demand management as part of an energy efficiency policy and thus cope with negative shocks of electricity supply in Chile.

Keywords: Electricity, Demand, Households

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I. Introduction

Since the early nineties, the demand for electricity in Chile has shown sustained growth.[1] Overall, this increase in consumption has been accompanied by increases in supply, although there have been drawbacks to meet demand in some periods. Both droughts and difficulties with the supply of gas from neighboring countries, particularly Argentina, have adversely affected the generation of electricity. In fact, because of the hydrological variability of the central zone of the country, as well as volatility in the availability of gas, episodes of power shortages have been inevitable (Diaz et al, 2000 and 2001; Galetovic et al, 2004). During some of these periods of decreasing electricity supply, rationing measures have been taken, including complete power outages for certain consumers.[2]

Faced with an unfavorable context in early 2008, the Chilean government took a series of measures to reduce energy consumption, seeking to avoid blackouts.[3] Some of these were directed towards residential demand, promoting the use of low power consumption light bulbs, extending daylight savings, and looking to encourage energy conservation through publicity campaigns. In 2008, there was also a price change through the inclusion of an additional month (April) for the purpose of measuring the peak hours of the electricity system, which officials said helped to reduce demand by an average of 3.7 GWh daily during its implementation. In addition, between March and October 2008, the decree of preventive rationing was applied, which allows distributors to discontinue service and forces them to compensate the regulated users. A reduction of up to 10% was established in the nominal voltage power supply of the distributors, the use of water resources was relaxed in order to have greater reserves and safety margins and also, a campaign of savings in the public sector was promoted, among other measures taken between 2007 and 2008.

Finally, in November 2008, the period of energy shortage ended. Between March and October of that same year, a lower average power consumption was recorded

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[1] *According to the National Energy Commission between 1990 and 2007, the total sales of electricity in the country grew at an annual average rate of over 8%. After the year 2000, the growth was less than that of previous years but still steadily increased at an average rate of 5.7%. Only in 2008 did power consumption decrease.*

[2] *In 1989 and 1990, customers were required to reduce their consumption by 10% for about 45 days. In 1998 and 1999, the supply was rationed and there were power outages to regulated customers (Serra, 2002). In 2008 and 2011 the voltage was reduced by 10% in urban centers to face the drought.*

[3] *The reason energy was at risk was because of a sustained drought, lower volumes of gas imported from Argentina, high international fuel prices, increased maintenance period in the Nehuenco Plant and lower ice thaw than was initially predicted.*

compared to the same period the previous year (-1, 61%) for the first time in a long while. Therefore, although the demand for electrical energy has shown a steady upward trend, it was possible to reduce consumption during an episode of supply shortage like in 2008. The scenario was repeated in 2011, where as a result of drought the government authorized a 10% decrease in voltage in urban areas and 12.5% in rural areas, with a new campaign for energy efficiency and savings in consumption of the public sector.

In this context, with a demand for electricity that continues to grow and a supply that is insufficient in certain periods, a deeper understanding of the behavior of the different agents relevant to electricity consumption generates essential information for the efficient regulation of the sector and can also give policy alternatives in cases of temporary shortage.

This work helps to identify the determinants of the demand for household electrical energy,[4] price and income elasticities in particular. For this purpose, the demand for residential electricity is estimated using data from the National Survey of Socioeconomic Characterization (Casen) 2006. The main advantage of this information is the data disaggregation on a household level, and also that it contains data for the whole country, including income information and other relevant sociodemographic characteristics, all of which are an improvement over previous studies.[5] In addition, the econometric specification comes from a demand function with micro foundations, derived from a utility function of constant elasticity of substitution (CES) for the energy consumption of households, allowing a structural interpretation of the estimated parameters.

The results for price elasticity are fairly consistent with some previous studies, with an estimated elasticity between -0.38 and -0.40 for residential consumption. The cross-price elasticity with respect to liquefied gas is robustly between 0.14 and 0.16, and the income elasticity is between 0.11 and 0.12. The results also show, as expected, that household consumption is significantly higher in Santiago, the capital and the largest city in the country, and in urban areas than in the other regions and rural areas, even though price elasticities are not statistically different.

Undoubtedly, the most relevant of these results is that the price elasticity found of -0.4 supports the adoption of demand management policies as part of a broader energy efficiency policy that serves to address negative supply *shocks* of electrical energy. This specific result is consistent with Benavente et al. (2005a) and Acuña (2008), and strengthens the proposals for using greater flexibility in the pricing of

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[4] *Residential consumption accounted for 16% of total domestic demand for electricity and 31% of sales to distributors (2006 and 2007).*
[5] *With the exception of Acuña (2008), who also uses household data.*

electricity as a real option to avoid rationing of residential electricity and the use of (Diaz et al., 2001; Chumacero et al, 2000; Benavente et al, 2005b). A system with automatic pricing could give the correct incentives for consumers to make efficient decisions without having to suffer quantity rationing or blackouts. In theory, the Chilean price system enables efficient allocation of energy in times of shortage. However, in situations of excess demand in the past it has not done so, and the lack of flexibility in setting the regulated price of electricity and the complexity of the compensation system were the reasons behind this failure (Diaz et al., 2000, Benavente et al., 2005a).[6]

Unlike developed countries, empirical economic literature about the demand for residential electricity is relatively small in Chile, especially those using household micro data since almost all studies use aggregate data. In Benavente et al. (2005b), residential electricity demand is estimated using panel data of monthly sales of 18 energy distribution companies of the Central Interconnected System (SIC) for the period between January 1995 and December 2001. Their results show that, although the magnitude of the price elasticity is relatively small (-0.0548 in the short run and -0.39 in the long run), it has a significant economic impact that can explain an important part of the increase in demand during periods when prices have fallen. On the other hand, Chumacero et al. (2000) estimate the price and income elasticities of the total aggregate demand (not just residential) using monthly data of total generation of SIC and node prices. Their results show a short-term price elasticity between -0.09 and -0.02, which the authors state that may be less than the effective residential value because of the assumption that the regulated customers demand is a constant fraction of total demand. These values are similar to those obtained by the National Energy Commission (1986), where the aggregate demand was estimated using annual data and the price elasticity obtained was between -0.09 and -0.04. Finally, Acuña (2008) estimates the electricity demand with disaggregated data and gets a price elasticity of -0.73, much higher in magnitude to the rest of the literature, including this paper, while Marshall (2010) estimates with aggregate data and obtains price elasticities between -0.37 and -0.44.

The rest of the paper is organized as follows: Section II reviews the literature of demand for electricity. Section III develops a microfounded demand model that determines the functional form of the demand to be estimated and then presents an analysis of the data used. Section IV presents the estimates and analyzes the main results. Finally, Section V concludes. An annex has been included with the general characteristics of the electricity market and energy consumption of

[6] *Díaz et al. (2000 and 2001) present a detailed discussion of the causes of lack of adjustment, establishing that a stronger involvement of the authorities could have allowed better management of scarcity.*

households in Chile, to contextualize the residential demand for electricity in the country.

II. Theoretical Considerations and Empirical Evidence

1. Short and Long Term Demand

Electricity demand is a derived demand since it is used as an energy source for the operation of appliances and equipment, which are those that provide the final services demanded by users. In general, the decision to consume residential electricity has three components, which are closely related and reinforce each other (Hartman, 1979): (i) the decision to buy or replace a durable good providing a service to the home (heating, lighting, cooking, entertainment, etc.), (ii) the decision over the technical characteristics of the device and the energy used by it to provide the service,[7] and (iii) the frequency and intensity of use of the purchased equipment.

Thus, electrical power does not generate utility in itself to consumers but contributes indirectly as an input for processes or activities that do result useful to individuals at home (Taylor, 1975). These activities, which generate utility and need electricity to operate, require an investment in durable goods, making it necessary to separate short-term demand, where the stock of durable goods is considered as given and then the relevant economic decision is the frequency or intensity of use, from long-term demand where consumers can modify their stock of durable goods.

While conceptually it is important to separate between short and long term demand, its empirical identification is not trivial. One of the pioneering works in doing so is Fisher and Kaysen (1962), where short-term elasticities are identified by directly controlling the stock of equipment, and long-term from a second equation that models the demand for equipment. However, this approach requires data on equipment stocks in the households, which is an important limitation.

This is how partial adjustment models emerge as a more feasible alternative because they do not require information on the stock of equipment. The main idea behind these models is that the desired consumption is determined by the consumer as if the stock of equipment was in its long-term optimum, which in reality does not occur because of the cost of adjusting the stock of equipment instantly to changes in prices (Berndt and Samaniego, 1984; Benavente et al, 2005a). Thus, it is possible to model the present energy consumption in terms of

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[7] *Technical details are the most relevant because they affect energy consumption, and also influence the decisions concerning design, size and other additional features not included in the basic service provided by the team.*

past energy and parameters that measure the speed of adjustment, allowing to distinguish the short-long term from the long term elasticities. One disadvantage, however, is that dynamic models show greater volatility in their results (Dahl, 1993).

A third approach explored in a complementary degree, is to estimate conditional demands, which considers energy consumption conditional on the stock and the heterogeneity of devices owned by each household along with the decision to purchase equipment (Parti and Parti, 1980; Bartels and Fiebig, 2000, Reiss and White, 2005). The major limitation in this case is the availability of panel data that include detailed information on the equipment present in households in each period.

In general, there is no consensus in the literature regarding the best way to identify the relevant elasticities of demand for electricity and most of the work, perhaps because of data availability, use single equation models. However, there is more agreement on the interpretation of the estimates depending on the type of data used. It is because of this that estimations done with cross-sectional data are considered long-term and time-series data as short-term (Bohi and Zimmerman, 1984). For this reason, the use of disaggregated panel data allows short and long term estimation simultaneously (Dahl, 1993).

2. Empirical Evidence

Theoretically, an increase in energy prices may lead to a decrease in consumption of the service for which this energy is used (and hence to a decrease in energy consumption) or to the substitution between energy sources. Additionally, being a derived demand, a price increase may lead to additional investments to obtain the same level of service in the end without having to increase spending on the same power source or replace the power supply with another (Sweeney, 1984). A good example of this latter effect is heating, where an alternative is to invest in greater thermal insulation instead of using another energy source. Obviously, this effect requires a longer period of adjustment just like the adjustment of equipment stock (new equipments are more energy efficient), which is why the short-term price elasticity should be lower than the long term, in absolute terms. The relevant question in the literature then focuses on determining the magnitude of the elasticities.

International empirical evidence shows results for the long-term price elasticity in a limited range between -0.7 and -1 (Taylor, 1977; Bohi and Zimmerman, 1984; Sweeney, 1984; Dahl, 1993).[8] In the short term, price elasticity estimations are found between -0.2 and -0.4 (Fisher and Kaysen, 1962, Anderson, 1973;

[8] *Most of the studies are for the U.S. or UK.*

Taylor, 1977, Dubin and McFadden, 1984; Bohi and Zimmerman, 1984; Dahl, 1993, Reiss and White, 2005).

There is some evidence that price elasticity would decrease as the level of household income rises (Reiss and White, 2005), which means that it is increasingly inelastic with higher income. There is also empirical evidence showing that it is lower in summer than in winter, which can be interpreted as the reduced ability to replace cooling electrical equipment relative to heating (Dahl, 1993; Filippini, 2002). The evidence in the literature is mostly for developed countries: the United States, Switzerland, England, Denmark, Norway and Australia, and to a lesser degree for some poorer countries: India (Bose and Shukla, 1999; Filippini and Pachauri, 2002); Namibia (De Vita et al, 2006); Cyprus (Zachariadis and Pashourtidou, 2007) and Lebanon, so the comparisons with Chile may not be as relevant (Nasr et al, 2000). One exception is the article by Galindo (2005) for Mexico, who uses aggregate data to estimate a short-term price elasticity between -0.18 and -0.24 and an income elasticity between 0.5 and 0.8.

The estimations for income elasticity, on the other hand, are rather sensitive to the type of data used. Estimates using household data show income elasticities around 0.4 and lower, while the estimates using aggregate data show higher elasticities, ranging between 0.5 and 1.

As mentioned in the introduction, empirical evidence for Chile is relatively scarce and infrequent compared with developed countries. In particular, empirical evidence from micro data about final consumers is almost nonexistent. A first effort to estimate the price elasticity of demand was made by the National Energy Agency (CNE) in 1986, using aggregate data which estimated short term elasticity between -0.09 and -0.04. Almost fifteen years later, also with aggregate data, Chumacero et al. (2000) estimate a short-term price elasticity between -0.099 and -0.024. Then, using panel data of distributor's sales, Benavente et al. (2005a) estimate a price elasticity of -0.0548 in the very short term (one month), of -0.27 in the short term (one year), and -0.39 in the long term (more than one year). Later, Acuña (2008) uses cross-sectional household data for 2006 and estimates a price elasticity of -0.73, much higher in magnitude to that found previously for Chile. Finally, with aggregate data at a county level, which blends residential consumption with that of small industries and trade, Marshall (2010) estimates a price elasticity of -0.37 in the short run and -0.44 in the long run.

The differences in the magnitude of the elasticities obtained in the various estimates can have a significant economic impact on the electricity market, particularly regarding potential public policies that can be implemented in times of scarcity. For example, Benavente et al. (2005a) analyze the impact on residential consumption if users perceived the opportunity cost of electricity during a shortage (and not the actual BT1 residential rate they pay). Their results show that, three months after the increase in price, demand would have fallen by 9.5%, which would have been sufficient to handle the energy deficit crisis in 1998-1999 which was close to 10%. If the price elasticity were lower than the one considered in this analysis, the conclusion would be different, and if it were much higher, as estimated by Acuña (2008), the demand management could potentially confront crisis of far greater magnitude than 10% deficit. Given this, it is important for Chile have robust evidence regarding the potential response of the demand to changes in electricity prices.

Additionally, given that generation costs grow exponentially when approaching the maximum capacity, a change of the demand close to its limits can have impacts of economic relevance (Albadi and El-Saadany, 2008), confirming the importance of having the most precise possible knowledge about the behavior of consumers.[9]

III. Model and Data

1. A Model of Energy Demand

The information that is available at a micro data level in Chile consists of cross-sectional data on monthly household consumption in KWh from the Casen Survey, which depends on the frequency and intensity with which households use their monthly stock of electrical appliances to consume the final services they supply, either lighting, cooking, heating or other.

The data therefore exclude the possibility of considering partial adjustment models for residential electricity demand, which are among the most widely used to estimate energy demand with time series data. While there are numerous estimates of energy demand with cross-sectional data in the literature, there is no standard model for doing so and in general the estimation is based on reduced form models with different econometric specifications (Houthakker, 1951; Wills, 1981; Dubin and McFadden, 1984; Halvorsen et al, 2003; Zarnikau, 2003, Fernandez, 2006, Yoo et al, 2007; Boonekamp, 2007).

In this paper, we propose to estimate a demand for residential electricity that comes from a process of households' utility maximization. For this purpose, it is assumed that consumer preferences can be expressed by a constant elasticity of substitution (CES) utility function:

$$u_i(x_{i1}, x_{i2}, z) = \left(x_{i1}^{\rho} + x_{i2}^{\rho} + z_i^{\rho}\right)^{\frac{1}{\rho}}$$

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[9] *In California´s case, for example, if the marginal price increases by 3 cents per KWh, a difference in the actual magnitude of the elasticity of -0.1 (-0.29 instead of -0.39) would yield an overestimation revenue of the companies around $ 75 million (Reiss and White, 2005).*

where x_{i1} is the amount of electricity that is consumed by household *i*, x_{i2} is the consumed amount of liquefied gas, and z corresponds to the consumption of all other goods. While household utility depends on the consumption of services provided by devices that require power to operate, the demand for these services within the household is implicitly considered through the amount of energy consumed in the utility function.[10]

Households maximize their utility given their budget constraint $y_i^{'} = p_1 \cdot x_{i1} + p_2 \cdot x_{i2} + z,$ where we have normalized the price of other goods to one $(P_z = 1)$. *Defining* $\alpha = \frac{1}{\rho - 1}$ *and* $y_i = y_i^{'} - z$, the demand function for household electricity i (x_{i1}) is:

$$x_{i1} = \frac{p_1^{\alpha} \cdot y_i}{p_1^{\alpha+1} + p_2^{\alpha+1}}$$

The price elasticity and cross price elasticity would be given by the following expressions:

$$\frac{\partial\, ln\ x_{i1}}{\partial\, ln\ p_1} = \alpha - \frac{(\alpha+1) \cdot p_1^{\alpha+1}}{p_1^{\alpha+1} + p_2^{\alpha+1}} \quad ; \quad \frac{\partial\, ln\ x_{i1}}{\partial\, ln\ p_2} = -\frac{(\alpha+1) \cdot p_2^{\alpha+1}}{p_1^{\alpha+1} + p_2^{\alpha+1}}$$

A potential problem with using this specification is that the income elasticity is equal to 1, and there is no robust evidence in the literature that allows this assumption to be a valid restriction. For this reason, this theoretical restriction in the econometric estimation is relaxed to allow the data to validate or not the assumption imposed by the use of the CES model.[11] For this, a parameter (β) is included in the income, which helps identify the impact that different levels of income have on the electricity demand. Additionally, the coefficients associated with price are relaxed (by multiplying the exponent γ by δ), and k variables are added with the geographic and demographic characteristics of the household (d_k). Thus, the demand function to estimate is:

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[10] *This way of modeling energy consumption is equivalent to the one proposed by Filippini (1999) that incorporates into the utility function an energy composite good, which consists of the consumption of electricity, natural gas and energy consuming appliances.*

[11] *This assumption arises naturally when considering that the demand for energy is derived from the use of indivisible durable goods, as well as direct divisible consumption (which may depend directly on the income). The indivisibility of the stock of durable goods in every home will lead to energy demands increasing in leaps with respect to income. Therefore, a growing demand for energy, even though concave with respect to each level of income, should be empirically found.*

$$x_{i1} = \frac{p_1^{\alpha} \cdot y_i^{\beta}}{p_1^{(\alpha+1)\cdot\gamma} + p_2^{(\alpha+1)\cdot\delta}} \cdot \exp\left(b_0 +_k b_k d_k\right)$$

$$\Leftrightarrow$$

$$\ln\ x_{i1} = b_0 + \alpha \cdot \ln\ p_1 + \beta \cdot y_i - \ln\left(p_1^{(\alpha+1)\cdot\gamma} + p_2^{(\alpha+1)\cdot\delta}\right) +_k b_k d_k$$

Whereupon price, cross-price for substitute energy and income elasticities are respectively given by:

$$\frac{\partial\, ln\ x_{i1}}{\partial\, ln\ p_1} = \alpha - \frac{\gamma \cdot (\alpha+1) \cdot p_1^{(\alpha+1)\cdot\gamma}}{p_1^{(\alpha+1)\cdot\gamma} + p_2^{(\alpha+1)\cdot\delta}} \quad ; \quad \frac{\partial\, ln\ x_{i1}}{\partial\, ln\ p_2} = -\frac{\delta \cdot (\alpha+1) \cdot p_2^{(\alpha+1)\cdot\delta}}{p_1^{(\alpha+1)\cdot\gamma} + p_2^{(\alpha+1)\cdot\delta}} \quad ; \quad \frac{\partial\, ln\ x_{i1}}{\partial\, ln\ y_i} = \beta$$

2. Data

The empirical analysis is performed using cross-sectional data per household for October and November 2006 from the National Socioeconomic Characterization Survey (Casen[12]), which is supplemented with price information from the National Energy Commission (CNE).

In the 2006 Casen survey, an energy component was included among the set of questions for the first time to determine the household consumption of different types of energy. Questions about the consumption of liquefied gas, piped gas and firewood were incorporated. Additionally, in the housing component of the survey, questions about the availability and consumption of electric power were added, collecting information on consumption in KWh and the expenses paid by households (Table 1).

$$Table\ 1$$

For the 2006 Casen, 73,720 households inhabited by 268,873 individuals representing 4,337,066 households and 16,152,353 individuals in the country were surveyed. Of the total number of people represented by the survey, 98.3% live in a home that was supplied electric power from the public meter network in 2006 (95% of households in the sample). Only this set of households was asked about the amount of electricity consumed in the previous month. Thus, the sample reaches nearly 70,000 households, of which 50% (34,072) answered the question about KWh consumed in the household the month prior to the completion of the

[12] *46% of households in the sample answered the question about consumption of energy for a single month (34,072 households), with 52% of respondents for October and 40% for November.*

survey (Table 2). The latter is relevant for the estimation since the non-response rate is high and the households who did or did not respond may not be random.

$Table\ 2$

Table 3 shows the use of other energy sources in the surveyed households. As seen in the table, 86.2% of the sample households used liquefied gas in cylinders, 61.4% used firewood and 4.4% piped gas. The composition changes significantly between households with electricity via the public network and those without. Among those who have access to the network, 87.6% use liquefied gas, 4.5% piped gas and 60.2% firewood. Among those who have no access to the public network, 61% use liquefied gas, 3% piped gas and 84% firewood.

$Table\ 3$

As a first look at the potential problem of selection bias in the sample, it is important to compare the use of different energy sources among households who answered the question about the number of KWh consumed and those who did not. As seen in Table 4, which shows the breakdown for households who answered the question, the proportion of households by energy source is quite similar to that of the total population, which is confirmed statistically in hypothesis tests comparing proportions of households who answered the question in the survey and those who did not.[13]

$Table\ 4$

Within this sample of 34,072 households, only those that do not share housing (97% of the total) are used in the empirical analysis since it is not possible to identify each household's consumption separately within the home.[14] Additionally, there are observations at both ends of the distribution that have values that are not plausible given the range of residential consumption reported by the electricity distributors, which is probably due to data errors. To avoid arbitrarily eliminating some specific implausible values, it was decided that 0.5%

[13] Including variables such as income, geography and other characteristics of the household (and of the head of household) the probability of answering the KWh consumption question was estimated in order to test the potential selection bias in the estimation of the demand with a Heckman-type econometric model. The results do not reject the null hypothesis of no selection bias.
[14] In these households, the average electricity consumption per month was 129 KWh, with an average cost of close to 14,000 Chilean pesos. In the case of gas, households consumed on average 15.6 kilos per month of liquefied gas cylinders, while the average consumption of piped gas (available for 982 households) was 125 m3 per month, which costs about 20,000 pesos per month.

of each tail of the distribution would be removed (1% of the sample) which, added to the lack of information for some variables, led to a final sample of 32,355 homes.

In the final sample of households, the monthly average electricity consumption was 129 KWh, with an average expense of close to 14,000 Chilean pesos. For gas, households consumed on average 15.6 kilos per month of liquefied gas cylinders, while the average pipeline gas consumption (available for 982 households) was 125 m^3 per month, costing about 20,000 pesos per month (Table 5).

$Table\ 5$

One of the most important elements in the estimation of the demand for electric power is the pricing information. For the Casen data, it is possible to calculate the implicit price per home for electricity, which is constructed from information on the total amount paid and the amount consumed. Since households face a two-part tariff it is necessary to subtract the fixed charge from the total expenditure on electricity to identify to price correctly. A price is therefore calculated for each household as $p_i = (g_i - f_c)/ q_i$, where g_i is the expenditure for electricity in the bill for that month, f_c is the fixed charge per county obtained from the CNE and q_i is the consumption in KWh per household reported in the Casen survey (Table 6)[15]. The fixed charges per county, which are obtained from public information given by the CNE for October of 2006, identify 48 different fixed charges and 61 variable rates ($/KWh) which correspond to the electricity supply services of 29 distribution companies. In addition to the implicit price, for the purpose of estimation robustness exercises the variable rate is used as the explicit price charged by distributors in each county. [16] The descriptive statistics for both prices are presented in Table 6.

$Table\ 6$

Finally, the price of liquefied-gas, which is the main energy substitute used in homes, is obtained from outside sources since the Casen survey does not provide spending information on liquefied gas. One of the difficulties concerning the price of liquefied gas is that it decreases with the amount consumed (due to the supply

[15] *In 30 of the original sample households, the expenditure reported in electricity is less than the minimum fixed cost which is charged in the county where the home is located. It is not possible to identify whether this is because these households are beneficiaries of the subsidy to electricity or is simply a data error. By removing 1% of the distribution, these observations are eliminated.*

[16] *Residential clients pay a regulated energy rate called BT1. The BT1 rate from air supply is considered for this purpose, since most of the residential consumption is provided in this way. The BT1 rate is obtained from the sum of the expected marginal costs, the capacity cost and the distribution cost, adjusted by average losses. Also, in the counties where more than one company covers the delivery or distribution service, minimum price is used, since most of the sample households are urban and the highest prices are found in rural areas.*

in discrete and fixed gas cylinder sizes). Therefore it is necessary to make some basic assumptions about rationality in household behavior for its estimation. On one hand, households may have budget constraints and buy as little as possible, and must then be assigned the highest price regardless of the level of consumption. On the other hand, households may seek to optimize consumption and purchase the amount needed to meet their demand, and must then be charged according to the price ranges of total consumption in the month. Assuming an optimizing behavior by households without strong liquidity constraints, liquefied gas prices are calculated for each of the sample households based on current prices in October and November 2006 for different sizes of gas cylinders in each of the regions (Table 7).[17]

$Table\ 7$

Additionally, variables are obtained from the Casen survey that can characterize the household in terms of income, number of people, size of the home (in the absence of surface area data, the number of bedrooms and bathrooms is used as a a *proxy*), the presence or absence of equipment and appliances that consume energy (washing machine, refrigerator, water heater, computer), use of other energy sources (wood, piped gas), if there is a commercial use of electricity at home *(Commerce dummy),* if the home is in an urban or rural area, and if the materials used in the construction of the home correspond to the most insulating or not *(Matbien dummy).* The descriptive statistics of the variables used are found in Table 8.[18] It is important to note that just 6% of households in the survey reported a commercial use of electricity besides residential use; therefore the estimated demand is primarily related to residential consumption.

$Table\ 8$

Additional variables were included in the econometric analysis that characterize the household head (gender, education, occupation) and the heterogeneity of the people in the household (children, elderly), but none was significant and the results did not change when they were omitted from the analysis. Similarly, fairly

[17] *For households that do not consume liquefied gas (N = 3,615), the price is imputed considering the equivalent power consumption in liquefied gas, according to the criterion of calorie conversion to the National Energy Balance 2006. Thus, although perfect substitution is assumed between liquified gas and electricity, what is sought is to estimate the range of energy consumption of the household in terms of liquefied gas to associate a price level accordingly. After the estimation, robustness tests are performed which impute the price of the cylinder as 15 kgs. per region.*

[18] *When comparing means of the distribution between the sample used in the empirical analysis and the entire sample of the CASEN, there are differences in some socioeconomic variables. For example, the average income in the total sample is $491.788, somewhat higher than the income used in the final sample, and also, the fraction of urban households is 61%, which is somewhat lower than the fraction in the sample used. This makes it even more relevant to control for observable socioeconomic variables in the estimated regressions.*

aggregated climatic variables (temperature, rainfall) were considered, as there is no disaggregated information on a county or regional level, but were also not significant. The climatic effects are most probably captured by the *dummy* regional variables since overall climate variation in Chile is strongly correlated with latitude and the geographical distribution of the regions.

IV. Estimation and Results

The evidence found in the literature consistently shows that demand for energy, in addition to price and income, is determined by household characteristics (number of people, electrical equipment, type of dwelling, number of rooms, etc..), characteristics of individuals (age, presence of minor children or elderly, employment outside the home, etc.) and climatic conditions. Considering this evidence, the previously proposed model of demand and the available information, the following econometric specification is used in the estimation:

$$\ln x_{i,electr} = b_0 + \alpha \cdot \ln p_{i,elect} + \beta \cdot y_i - \ln \left(p_{i,elect}^{(\alpha+1)\cdot\gamma} + p_{i,GLP}^{(\alpha+1)\cdot\delta} \right) + \sum_{k=1}^{12} \sigma_k \cdot r_{i,k} + \sum_{k=13}^{22} \sigma_k \cdot z_{i,k} + \mu_i \quad (1)$$

where the variables P_{elect} and P_{GLP} correspond to the prices of electricity and liquefied gas that household i faces, respectively; $z_{i,k}$ are household characteristics (previously described in Table 8) and $r_{i,k}$ are regional *dummies*.

Table 9 presents the results of estimating equation (1) with nonlinear least squares, correcting for heteroscedasticity. One of the possible sample selection bias is related to the use of piped gas as it is not random which households have access to piped gas and which do not. For this reason, the model is estimated in two ways. First, including a *dummy* for access to piped gas. Second, considering a selection equation for the access to piped gas and estimating standard errors with *bootstrapping* (1000 repetitions). Both results are presented in the Table.[19] Even though the coefficient associated with the inverse Mills ratio is statistically significant (*lambda*), which reflects some degree of selection bias, the impact of this bias in the estimated coefficients is not important in magnitude.

Table 9

Overall, the results are quite satisfactory in the sense that the regression can explain a significant proportion of the variance in the data and all the variables are

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[19] *We also considered the potential selection bias in the sample of households that answered the energy questions in the survey. Results in various different specifications never rejected the null hypothesis of no selection bias.*

significant and have the expected signs. The presence of artifacts and equipment increases electricity consumption in the home, as well as a greater number of people and larger numbers of rooms and bathrooms. On the other hand, homes with better insulation consume less electricity. The effect, as expected, is smaller in magnitude than the impact of other variables because it is mostly limited to energy consumption associated with heating.

In terms of magnitude of the effects, an increase of one person in the average number of inhabitants of the household increases the demand for electricity in 7.6%; having a refrigerator increases the average electricity consumption by 32.9%; having a computer in 19.8%; having a washing machine, in 11.5%; and having heating, in 6.5%, everything else constant. Homes with an additional bedroom or bathroom have a higher average consumption of 6.5%, and thermal insulation reduces it by -2.7%. Finally, a home that has commercial consumption has a 38% increase in demand compared to households that only have residential consumption.

Price and income elasticities are calculated from the estimated parameters, evaluated at the mean and median of the respective variables (price of electricity, price of liquefied gas, and income). Confidence intervals for each elasticity are obtained using the *delta* method. The estimated elasticities are shown in Table 10.[20]

$Table\ 10$

The price elasticity of the residential electricity demand in Chile is estimated consistently in a range between -0.36 and -0.43. The point estimates of the elasticity are obviously in a more limited range between -0.38 and -0.4. [21] This result is similar to other empirical findings in the literature: in particular, the magnitude is very close to that obtained by Benavente et al. (2005b) and Marshall (2010) for Chile (-0.39), Reiss and White (2005) for California (-0.39) and Halvorsen and Larsen (2001) for Norway (-0.44). However, the result of Acuña (2008) for Chile, who also uses household survey data, shows a much higher price elasticity. A plausible explanation for the difference in the results is that the average price per KWh in Acuña´s work is calculated without deducting the fixed charge paid by the households (or deducting the same average fixed charge to all

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[20] *Additionally, price elasticities were estimated through interactions in the delta parameter for households in urban areas (-0.416) and rural (-0.394) but statistically it is not rejected that they are the same. .Similarly, price elasticities were estimated for the Great North Area of the country (-0.413) and the Extreme South (-0.40), and it is also not rejected that they are equal.*

[21] *Considering the implicit price of electricity obtained from Casen, the average price is 131.6 $/KWh, whereas the median price is 94.73 $/KWh. The latter is close to the explicit average price obtained from CNE data (91.04 $/ KWh).*

households in the country), which would lead to an overestimation of the price elasticity.

The estimated income elasticity is 0.11 with confidence intervals in a range between 0.10 and 0.13. A fairly inelastic income demand like the one estimated is coincident with the main results found in the literature. Reiss and White (2005) estimate a completely income inelastic demand for California; Parti and Parti (1980) estimate an income elasticity of 0.15 for San Diego; Halvorsen and Larsen (2001) estimate between 0.06 and 0.13 for Norway; and Garcia-Cerruti (2000) estimate 0.15 for California. For Chile, preliminary estimates show a higher income elasticity, around 0.2 by Benavente et al. (2005b) and Acuña (2008), and between 0.5 and 0.8 by Marshall (2010). It has to be taken into account, however, that in several of these empirical works for Chile the existence of durable goods in the household is not controlled for, which would potentially skew upward the estimated income elasticity.

For the cross-price elasticity between electrical energy and liquefied gas, the estimate reflects a certain degree of substitution between both energy sources. On average, a 1% increase in the price of liquefied gas is associated with an increase of 0.16% in the demand for electricity, all else equal. The confidence interval of the cross-price elasticity is slightly higher than in the case of the other estimated elasticities, ranging between 0.09 and 0.21. Again this result is similar to that found by Benavente et al. (2005b) for Chile and close to the average result in the literature of 0.18 for the elasticity with respect to natural gas (Dahl, 1993). However, in the only other specific result for liquefied gas in the economic literature, Dubin and McFadden (1984) estimate a higher degree of substitution with a cross elasticity of 0.39 for U.S. households.

Finally, it is important to note that the interpretation of the results obtained in the estimation of the demand for residential electricity in Chile corresponds to long-term elasticities, when households are in equilibrium with respect to the amount owned of durable goods that consume electricity. The reason is mainly due to econometric identification, because when cross-sectional data is used the identification comes from differences in energy consumption among different households in steady state. On the contrary, the identification of the elasticity of short-term demand would require also having variation in the data within households over time, ideally for several months in a row.

V. Conclusions

Several issues related to energy are becoming increasingly important in various economies around the world. In particular, there is a great concern about the strong growth of demand for energy versus energy supply. Chile is no exception to this trend and, as the country faces energy deficits, policies for energy efficiency and demand management are becoming increasingly important. The implementation and design of such policies require, however, a greater understanding of the behavior of economic agents in their energy consumption. Robust evidence on the magnitudes of price and income elasticities of the demand for electric power is particularly required.

In this context, a price elasticity of residential electricity consumption is estimated by using disaggregated data per household in Chile for 2006. The results obtained allow us to conclude robustly that consumers do modify their electricity consumption in response to price changes. The magnitude of this effect is consistently estimated to be between -0.38 and -0.4, which is similar to that estimated for Chile by Benavente et al (2005a) and for California by Reiss and White (2005). Even though the demand is relatively price inelastic, it is not completely inelastic, which implies that it is possible to generate important changes in consumption, in order to reduce the risk of power cuts in deficit situations, through changes in pricing.

Additionally, the results show that there is some degree of substitution between some energy sources within households. The price elasticity of electricity consumption with respect to the price of liquefied gas is estimated between 0.14 and 0.16. The accuracy of the estimate, with a confidence interval between 0.09 and 0.21, is lower than the one for the elasticity with respect to the price of electricity. However, it is informative for the proper design of demand management policies to know that the pattern of substitution in the consumption of electricity when a price change occurs is not only because of changes in electricity consumption, but also because of the substitution to other energy sources.

Finally, knowing the magnitude of the price elasticities of the demand for electricity with precision also allows a correct estimation of the effects, on efficiency and revenue, of the implementation of taxes that incorporate potential negative externalities of energy consumption on climate change (Azevedo et al, 2011).

In future research, it would be relevant for Chile to extend the empirical analysis of this paper in order to identify the seasonal change in housing demand, since in some periods (in different months of the year), the behavior may be more inelastic than estimated. This analysis requires having panel data at a household level, for different periods of time during each year, which is currently not available for Chile.

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Table 1: Survey Information

Energy	Variable Code	Description
Electricity	V7A	Electric Energy Available in the Household
	V7B_MES	Month of the Last Available Electricity Bill
	V7B_KWH	Monthly Electric Consumption in KWh based on Last Bill Available
	V7B_MON	Bill Paid for Monthly Consumption
	V7C	Electricity Consumption Higher than 40 hours a month in the Household for Commercial Purposes
Bottled Gas	V30	Use of Bottled Gas in the Household
	V30A	Average Monthly Bottled Gas Consumption
Piped Gas	V31	Consumption of Piped Gas
	V32A	Month of the Last Piped Gas Bill
	V32B_M3	Monthly Piped Gas Consumption in M3 Based on Last Bill
	V32B_LTR	Monthly Piped Gas Consumption in Liters Based on Last Bill
	V32C	Piped Gas Consumption Higher than 40 hours a month in the Household for Commercial Purposes
Wood	V29	Use of Wood in the Household
	V29A	Wood Consumption in Kilos

Table 2: Availability of Electricity in the Household

v7a: The House where you live, Does it have Electricity Access			**Information about KWH**	
	# Households	**%**	**# Households**	**%**
Yes, from public network and own meter	64,720	87.79%	32,612	50%
Yes, from public network and shared meter	5,213	7.07%	1,460	28%
Sub-total	*69,933*	*94.86%*	*34,072*	*49%*
Yes, from public network without meter	996	1.35%		
Yes, from own generator	893	1.21%		
Yes, from Solar Equipment	237	0.32%		
Yes, from another source	148	0.20%		
No	1,500	2.03%		
No Information	13	0.02%		
Total	**73,720**	**100%**		

Table 3: Energy Sources Used in the Households
(number of households)

	Electricity	Bottled Gas			Piped Gas			Wood		
		Yes	No	N/A	Yes	No	N/A	Yes	No	N/A
Yes, from public network and own meter	64,720	56,838	7,872	10	3,098	61,602	20	38,826	25,881	13
Yes, from public network and shared meter	5,213	4,424	789		63	5,149	1	3,297	1,915	1
	69,933	*61,262*	*8,661*	*10*	*3,161*	*66,751*	*21*	*42,123*	*27,796*	*14*
		87.6%	*12.4%*	*0.0%*	*4.5%*	*95.4%*	*0.0%*	*60.2%*	*39.7%*	*0.0%*
Yes, from public network without meter	996	729	266	1	36	958	2	738	257	1
Yes, from own generator	893	665	227	1	42	850	1	722	171	
Yes, from Solar Equipment	237	161	76		2	235		221	16	
Yes, from another source	148	95	53		16	132		107	41	
No	1,500	661	839		3	1,497		1,374	126	
No Information	13	8	3	2		13		9	2	2
	3,787	*2,319*	*1,464*	*4*	*99*	*3,685*	*3*	*3,171*	*613*	*3*
		61.2%	*38.7%*	*0.1%*	*2.6%*	*97.3%*	*0.1%*	*83.7%*	*16.2%*	*0.1%*
Total	**73,720**	**63,581**	**10,125**	**14**	**3,260**	**70,436**	**24**	**45,294**	**28,409**	**17**
		86.2%	**13.7%**	**0.0%**	**4.4%**	**95.5%**	**0.0%**	**61.4%**	**38.5%**	**0.0%**

Table 4: Households with Information on Electricity Consumption

(energy sources used)

	Bottled Gas		Wood		Piped Gas	
Yes	30,280	88.9%	21,923	64.3%	1,433	4.2%
No	3,790	11.1%	12,145	35.6%	32,632	95.8%
N/A	2	0.0%	4	0.0%	7	0.0%
Total	34,072	100.0%	34,072	100.0%	34,072	100.0%

Table 5: Summary Statistics for Residential Energy Consumption

(only households used in the estimation, N=32.355)

Variable	N	Mean	Std. Dev.	Min	Max
Electricity (KWh/month)	32,355	129.27	90.88	6	699
Bottled Gas (K/month)	28,722	15.63	13.21	1	200
Piped Gas (M3/month)	982	125.25	170.14	1	977
Wood (Kilos/Annual)	20,797	5,632.59	7,626.82	3	94,000
Ch$/month					
Electricity	32,355	13,703	9,786	921	213,874
Piped Gas	1,299	20,626	15,587	651	141,530
Natural Gas	877	20,374	14,610	651	135,862

Table 6: Electricity Prices

N	Unique Values	Mean	Std. Dev.	Min	Max
Implicit Price (Ch$/KWh)					
32,355	27,461	113.597	115.362	0.195	4,761.166
Explicit Price					
(Ch$/KWH)	61	91.041	15.706	68.581	131.926
Fixed Fee	48	955.427	205.729	542.320	1,362.220

Table 7: Price of Bottled Gas (Ch$/kg)

Region	Bottle Size			
	5 kg	11 kg	15 kg	45 kg
I	970.0	814.8*	806.9	758.3
II	980.0	823.2*	805.7	757.0
III	906.8	777.9	772.3	748.1
IV	889.2	736.6	742.2	720.9
V	884.0	764.4	728.0	709.6
VI	852.2	741.5	690.6	707.1
VII	867.6	713.3	708.2	695.0
VIII	879.6	756.4	713.3	696.9
IX	888.0	757.3	726.3	706.0
X	862.6	749.4	715.1	705.7
XI	1,017.6	750.0	818.0	777.1
XII	933.4	787.9	700.0	703.7
RM	894.4	721.0	702.0	687.2

Table 8: Summary Statistics

Variables	Mean	Std. Dev.	Min	Max
Q Consumed (Kwh)	129.27	90.88	6	699
Average Household Income	459,083	660,663	486	36,455,920
Number of People in the Household	3.70	1.71	1	16
Number of Bedrooms and Bathrooms	3.58	1.30	1	16
Washer	0.55	0.50	0	1
Refrigerator	0.86	0.35	0	1
Hot Water Boiler	0.47	0.50	0	1
Computer	0.21	0.41	0	1
Urban	0.67	0.47	0	1
Commercial Use	0.06	0.24	0	1
Insulated Materials	0.61	0.49	0	1
Wood	0.65	0.48	0	1
Piped Gas	0.04	0.20	0	1

Table 9: Estimation Results

Dependent Variable: lnQ		
Variable	**Piped Gas Dummy**	**Selection Bias**
$lnp_{electricity}$	-1.410 * (0.102)	-1.391 * (0.100)
lny	0.109 * (0.005)	0.116 * (0.005)
gamma	2.863 * (0.518)	2.957 * (0.557)
delta	2.707 * (0.431)	2.781 * (0.462)
Commerce	0.330 * (0.014)	0.326 * (0.014)
Wood	0.036 * (0.009)	0.026 * (0.009)
Number of People	0.075 * (0.002)	0.073 * (0.002)
Bedrooms and Bathrooms	0.061 * (0.003)	0.063 * (0.003)
Insulated Materials	-0.029 * (0.007)	-0.027 * (0.007)
Washer	0.110 * (0.007)	0.109 * (0.007)
Refrigerator	0.288 * (0.012)	0.285 * (0.012)
Hot Water Boiler	0.059 * (0.008)	0.063 * (0.008)
Computer	0.167 * (0.008)	0.181 * (0.008)
Urban	0.033 * (0.008)	0.034 * (0.008)
Piped Gas	0.049 * (0.016)	-
lambda	-	0.423 * (0.069)
bo	3.733 * (0.116)	3.321 * (0.136)
Regional Dummies	Si	Si
N $\mathbf{R^2}$	32,355 0.3831	32,355 0.3835

Stadard Errors in parenthesis
* Significant at 1%.

Table 10: Price and Income Elasticities

	Piped Gas Dummy		Selection Bias	
Elasticities	Evaluated at the Mean	Evaluated at the Median	Evaluated at the Mean	Evaluated at the Median
Price	-0.403 (-0.43,-0.38)	-0.381 (-0.40,-0.36)	-0.407 (-0.43,-0.38)	-0.384 (-0.41,-0.36)
Income	0.109 (0.10,0.12)	-	0.116 (0.11,0.13)	-
Bottle Gas	0.157 (0.11,0.21)	0.136 (0.09,0.18)	0.162 (0.11,0.21)	0.141 (0.09,0.19)

95% Confidence Interval in parenthesis