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Price elasticity of demand for fuels by income level in Mexican households☆

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ABSTRACT

The price elasticities demand of electricity, gas, oil fuel, gasoline and steam coal are estimated using household surveys from 1992 to 2014. The analysis uses alternative econometric techniques – OLS, SURE, and Quadratic Almost Ideal Demand System (QUAIDS) – the last of which is based on the methodology of Banks, Blundell and Lewbel considering socioeconomic characteristics of the households to account for the difference in demand of energy related goods. It is found that the demands for fuels are price inelastic, and the differences in elasticities between poor and non-poor households are small but statically significant. The income elasticity of demand is generally found to be positive and higher in absolute value than price elasticity, and the differences are greater between poor and non-poor. Consequently, there would be a differentiated reaction of consumers to changes in energy prices according to their poverty status. Steam coal and firewood, each of which could be considered inferior goods, stand as counterexamples in that the income elasticity is found to be negative. The contribution of this study helps policy makers to analyze household welfare when applying changes in energy prices in the face of fiscal and/or energy reforms, such as those Mexico is implementing.

1. Introduction

In 2010, Mexico committed to reduce up to 30% of its greenhouse gases emissions (GHG) by 2020 compared to a baseline scenario, and 50% in 2020 by 2050. This commitment is a challenge for a country in which energy infrastructure needs improvement, energy services are provided historically by government monopolies, the economy is highly dependent in oil price and remittances, and high-stake reforms made by a previous administration – spanning energy, fiscal, labor and education – are being reversed. In addition, the latest poverty measures reveal that poverty has increased, a signal that something in the socio-political construct in Mexico is not helping the fight to reduce poverty. Measuring the collective impact of strategies that aim to reduce greenhouse emissions and reduce poverty starts with analyzing energy consumption in poor and non-poor households, accounting for the official definitions of poverty used to design social programs and energy pricing decisions.

The provision of basic services to the entire population in Mexico has been steadily increasing in the last few decades. This can be seen with various energy services, as the percentage of the population connected to the electricity grid has increased 70 percentage points in the last 55 years (see in Graph 1). However, the services that are provided to a substantial percentage of the population come from government monopolies through pricing schemes that are highly regulated with relatively low-quality. For instance, electricity blackouts have occurred in major areas of the country when power demand is high; potable water is not provided to all municipalities; and, some communities do not have distribution pipelines to receive natural gas, which forces them to use alternative, often less environmentally benign energy sources for heating and cooking.[1]

Electricity service is provided by the Federal Commission of Electricity (CFE), a regulated institution of the Mexican government. Past research using CFE tariffs and average consumption has shown that short run price elasticities range from −0.348 at national level to

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[1] In fact, many poverty studies in Mexico use the variable “ownership of an electric domestic appliance” as proxy of electricity infrastructure in the area; the same happens with the variable “ownership of a gas stove”.

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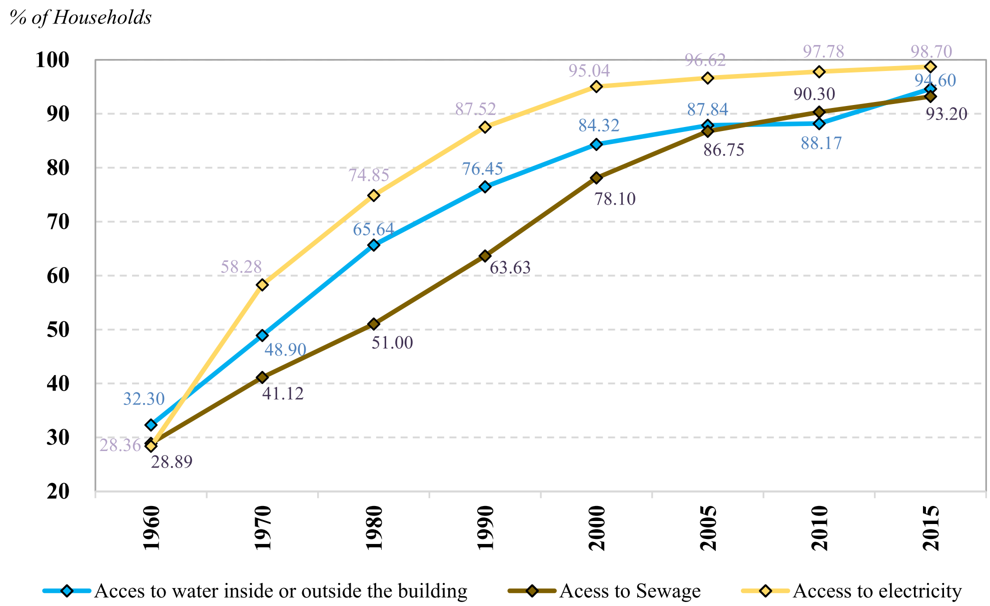


Graph 1. Tendency of household access to basic services.
Source: Authors' elaboration using data from INEGI. [A]
[A] INEGI is the National Institute of Statistic and Geographical Information in Mexico.

Table 1
Factors considered as relevant when calculating price and income elasticities.

Factors	Previous Studies	Our Research
Sample period: short/long term	yes	yes
Level of aggregation: household vs region	yes	yes
Product aggregation	one product	basket of products
Linear regression/Quadratic	linear	both
Household Budget Simultaneous estimation	few	yes
Endogeneity (IV estimation)	yes	yes
Household Characteristics	yes	yes
Poverty Condition	no	yes
Climate/Regional Characteristics	few	yes

Source: Author's own classification

−0.036 at pooled-regional level, and the long run price elasticities range from −0.811 to −0.107 (Berndt and Samaniego, 1984). These range of results indicates that electricity demand is relatively inelastic with respect to price.

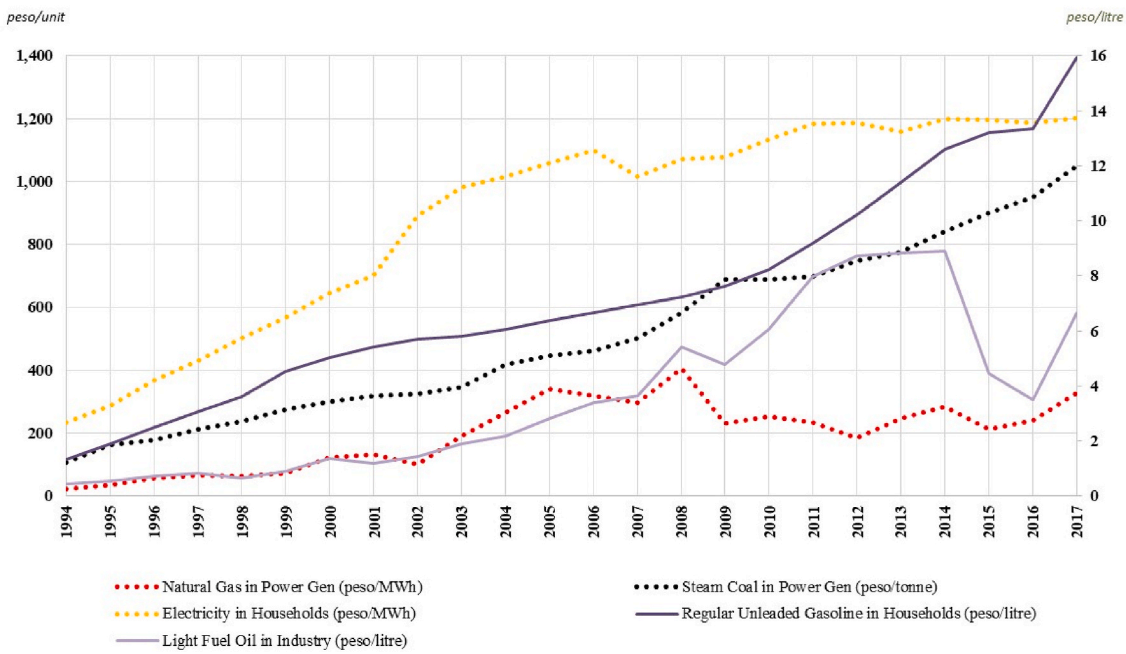
The prices of gasoline are regulated by PEMEX, Mexico's national petroleum company. Household consumption of gasoline and diesel is highly influenced by the availability and use of public versus private transportation. Public transport in Mexico is expensive compared to its quality; it is also insecure and unreliable, has poor regional coverage, and its closest substitute is private shuttles that operate without quality control. As a result, when income increases, households tend to purchase private motor vehicles rather than continue to use public transport. (Crôtte et al., 2010) found that price elasticities of gasoline change over time and differ between the national and local levels, with smaller price responses in Mexico City where the long run price elasticity ranges from −0.2 to −0.26. Previous gasoline demand surveys based primarily on national-level data report average elasticities between −0.6 and −0.8. Crôtte, Noland and Graham (2009) also calculated the use of transport measured by traffic in Mexico City, and found that the combined elasticities of income and vehicle stock are close to unity, while the elasticity for metro fares is negligible, which suggests there is little substitution between transport types.

Natural gas is used for cooking and heating in many places across the country, but households in rural areas use substitutes, like firewood or fuel oil. Domestic natural gas production is not sufficient to meet local demands, so Mexico has become a major importer of natural gas, especially by pipeline from the US. The required expansion of infrastructure to serve local needs coupled with rising imports has generally pushed up the price of natural gas service in the last few years. Bacon, Bhattacharya and Kojima (2010) point out that to study the well-being of households, it is necessary to analyze the patterns of expenditure on electricity, petroleum products (kerosene, gasoline, diesel, and liquefied petroleum gas), natural gas, and transportation at different income levels while also distinguishing between rural and urban areas and the impact on affordability of changes in prices and/or subsidies.

In general, available studies for Mexico regarding energy demand are concentrated at the sector level, not at household level. For instance, Galindo (2005) uses annual data for sectoral energy consumption in agriculture, industry, residential and transport covering the period 1965 to 2001. A relative energy index price is calculated as the ratio between the energy price index of electricity and fuels and the consumer price index. Galindo (2005) finds that "*demand for energy is driven by income and that the effect of the relative prices is basically concentrated on the short run with the exception of the industrial sector, which also shows a long-term price impact.*"

The aim of this paper is to calculate, for first time to our knowledge, the price elasticity of demand for energy goods for poor and non-poor households using household surveys and real prices of energy fuels.[2] In the next section, we summarize the literature on short-run and long-run price elasticities using different data and methods. In sections 3 and 4, we explain the methods and data, respectively, employed in this analysis. Section 5 presents the results, followed by concluding remarks

[2] These surveys are bi-annual, given that the households in each survey are not the same, so it is not possible to know if the households have switched to a more efficient technology in appliances. Hence, rebound effects cannot be calculated. For instance, for air condition (AC) we know that since 2002, on average, households show and increase in AC appliances, from 7.33% in 2002 to 13.91% in 2014.



Graph 2. Selected Nominal Fuel Prices (IEA).
Source: Authors' own elaboration using prices from IEA.

Table 2
Population in income poverty.

Year	Millions of people	% of Total Population
1992	46.1	53.1
1994	47.0	52.4
1996	64.0	69.0
1998	60.7	63.7
2000	52.7	53.6
2002	50.4	50.0
2004	48.6	47.2
2005	48.9	47.0
2006	46.5	42.9
2008	53.4	47.8
2010	58.5	51.1
2012	61.4	52.3
2014	66.1	55.1

Source: Authors' own elaboration using patrimony poverty measures from CONEVAL.

in section 6.

2. Previous literature

There are several meta-analyses about the estimated elasticities for energy fuels, most of them for natural gas, gasoline, and heating oil. These analyses present various explanations for the range of elasticities across various studies, such as differences in estimation methods (cross-section, time series or panel), functional forms of the estimated equations (linear, quadratic, systems), and datasets used (household surveys, enterprise data, governments reports, etc.).

According to Miller and Alberini (2016), price elasticities of energy (electricity) vary due to several factors: sample period, level of aggregation, use of different econometric techniques that account for heterogeneity or endogeneity, and inclusion of household characteristics. They used linear specifications to reveal energy price elasticities for the US that range from −1.11 to −0.08, and from −1.25 to −0.07 in some OECD countries.

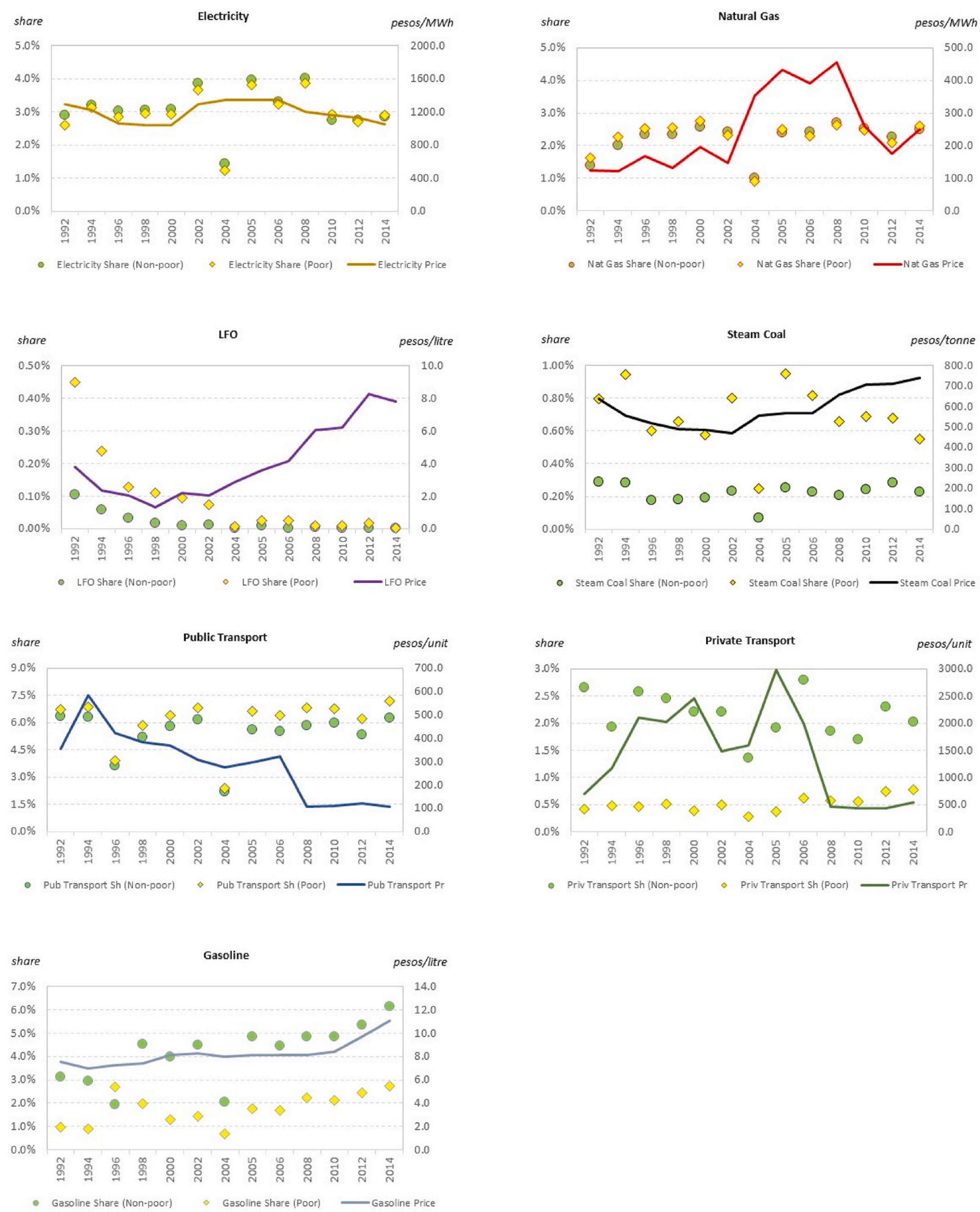
Hansen (2018) estimated price elasticities for energy used for heating, noting that heating services are important in household everyday life decisions. They find that the effects are stronger in higher income households, with elasticities in USA, UK and Norway that range from −0.73 to −0.02.

Dahl (2012) reviewed 240 studies on income and price elasticities of demand for transport fuels in more than 70 countries. They all use linear regressions. Removing outliers that found positive elasticities, the modal range of (−0.41 to 0). For Mexico is the price elasticity is −0.31 (for gasoline) and −0.30 (for diesel). Baltagi and Griffin (1983) find estimates for the price elasticity of gasoline that fluctuates from −0.55 to −0.90. They conclude that the estimates depend on the econometric technique, whether it is pooled data and if the method accounts for the heterogeneity across time and countries, suggesting that pooled cross-section/time-series data makes the estimation more efficient compared to cross-sectional regressions country by country.

Labandeira et al. (2017) conducted a meta-analysis on the price elasticity of energy demand. They collected 428 papers published between 1990 and 2016 with 966 short run elasticities and 1010 long run elasticities. They used their analysis to identify various factors across the studies referenced that impact the short and long run price elasticities for energy and select energy products, such as electricity, transport fuels and heating fuels. They also find that energy is price inelastic in the short and long run.

Several studies have focused specifically on energy use in Mexico. For example, (Berndt and Botero (1985) , and Eskeland and Feyzioğlu, 1997) focused on the demand for energy in transportation – focusing on rail, air and motor vehicle use – in Mexico. The authors created a fuel price index for railroad, using the transformed quantities of the two fuels (diesel and fuel oil for 1960–79). In the case of air transportation, they use a system of equations combining domestic and foreign demand for jet fuel, and in the case of motor vehicles, the data is pooled cross-section and time-series for the 32 states for 1973–78. The principal finding is that changes in income play a more important role in affecting energy demand than do changes in energy prices, especially in the railroad and air transport sectors. For gasoline and diesel fuel demand in the motor vehicle sector, however, price is of substantial importance.

Recently Rosas, Bakhat, Rosas and Fernández (2017) estimated a linear demand equation based on Deaton and Muellbauer (1980) called Almost Ideal Demand System (AIDS). They use the biannual Mexican



Graph 3. Expenditure shares (non-poor and poor) and real 2010 prices.

Table 3
Two-sample t-test, unequal expenditure share variances, poor and non-poor.

Fuel	Non-poor	Poor	Diff.	T-test	p-value
1- Electricity (Household)	0.0315	0.0307	0.0008	4.1506	0
2- Natural Gas (EGEN)	0.0226	0.0233	−0.0007	−4.9579	0
3- Light Fuel Oil (Industry)	0.0001	0.0007	−0.0006	−20.6868	0
4- Steam Coal (EGEN), Firewood and other fuels	0.0022	0.0069	−0.0048	−54.4896	0
5- Fuel appliances	0.0012	0.0008	0.0003	8.6657	0
6- Public Transport	0.0540	0.0616	−0.0075	−22.5653	0
7- Private Transport	0.0206	0.0052	0.0153	66.6484	0
8- Gasoline	0.0428	0.0185	0.0242	99.3259	0
9- Rest of the budget	0.8251	0.8521	−0.0270	−54.5481	0

Note: The # of observations for non-poor are 122,648 and 102,764 for poor.

Table 4
QUAIDS estimated price and income elasticities, Mexico, 1992–2014 (ex-2004).

	Price elasticities				Income elasticities	
	Poor uncomp	Poor comp	Non-Poor uncomp	Non-Poor comp	Poor	Non-Poor
1- Electricity (Household)	−0.71	−0.69	−0.72	−0.70	0.44	0.23
2- Natural Gas (EGEN)	−0.84	−0.82	−0.83	−0.81	0.92	0.84
3- Light Fuel Oil (Industry)[a]	−0.57	−0.57	1.18	1.18	0.77	0.46
4- Steam Coal (EGEN), Firewood and other fuels	−0.65	−0.65	0.09	0.09	0.24	−0.36
5- Fuel Appliances[a]	−0.89	−0.89	−0.92	−0.92	1.01	1.01
6- Public Transport	−0.83	−0.76	−0.78	−0.71	1.30	1.30
7- Private Transport	−0.08	−0.06	−0.76	−0.72	2.71	2.29
8- Gasoline	−1.00	−0.97	−1.00	−0.94	1.21	1.18
9- Rest of the budget	−0.95	−0.12	−0.94	−0.14	0.98	0.99

[a] Price elasticity is not statistically significant. Applies to 3-Light Fuel Oil (Industry) and 5-Fuel Appliances.
Source: Author calculations.

Household Surveys from 1994 to 2010, and estimated a price elasticity of demand for electricity of −0.61, for gas −0.34, and for gasoline −0.72. They ignored the quadratic term emphasized by Banks et al. (1997), which is observed in the pattern of household expenditure for several goods.

In this paper, we account for all of the factors mentioned above, and we consider linear and quadratic functional forms. In doing so, we estimate the price and income elasticities for each good separately with OLS, and simultaneously for all using the AIDS and the Quadratic Almost Ideal Demand System (QUAIDS) models. We also allow for regional differences and climate variables that may affect the demand for fuels, and, for first time to our knowledge, poverty condition. The general objective is to estimate a consistent set of price elasticities for products that include transport fuels, non-transport fuels, fuel appliances, public transport, and private transport. Table 1 provides a general summary of the breadth of our approach relative to previous research. Our objective is to estimate reliable price elasticity of demand for fuels in order to contribute to the debate over public policies directed at addressing energy access for poor households.

3. Methodology

As discussed in the previous section, different methodologies have been used to estimate price elasticities of demand. So, in this paper we estimate the price elasticity of demand for each fuel using ordinary least squares (OLS), and we estimate the price elasticity of demand for each fuel in a system of equations using seemingly unrelated regression (SUR), AIDS and QUAIDS.

The methodology of Banks et al. (1997) with QUAIDS takes into account social characteristics of the agents and the quadratic pattern that some household expenditures follow, and it is compatible with microeconomic principles of utility and demand systems. The demand system has the advantage that takes into account how the budget of the household is allocated across goods. This allows one to consider the effects that changes in price for a type of fuel will impact the consumption of complementary goods. For instance, the system allows one to identify how changes in the prices of gas and electricity impact the household demand for fuel appliances, and how changes in the price of gasoline impact the use of public and private transport.

The system approach requires the household to optimize the allocation of resources according to their utility function. The indirect utility of the household is specified as follows:

$$\ln V(p,m) = \left\{ \left(\frac{\ln m - \ln a(p)}{b(p)} \right)^{-1} + \lambda(p) \right\}^{-1}$$

where p_i is the price of good i, $b(p) = \prod_{i=0}^{n} p_i^{\beta_i}$ is a function that aggregate prices, $\lambda(p) = \sum_{i=0}^{n} \lambda_i \ln p_i$ and $\ln a(p) = \sigma_0 + \sum_{i=0}^{n} \alpha_i \ln p_i + \frac{1}{2} \sum_{i=0}^{n} \sum_{j=0}^{n} \gamma_{ij} \ln p_i \ln p_j$. Utility is maximized subject to homogeneity restrictions and Slutsky equations

$$\sum_{i=0}^{n} \beta_i = 0, \quad \sum_{i=0}^{n} \lambda_i = 0, \quad \sum_{j=0}^{n} \gamma_{ij} = 0, \quad \gamma_{ij} = \gamma_{ji}, \quad \text{and} \quad \sum_{i=0}^{n} \alpha_i = 1.$$

Denoting q_i as the quantity consumed of each good i, we note that $w_i = \frac{p_i q_i}{m}$ is the percentage of total household expenditure, m, spent on each good. Following (Banks et al., 1997) and using Roy's identity, we obtain each expenditure share as

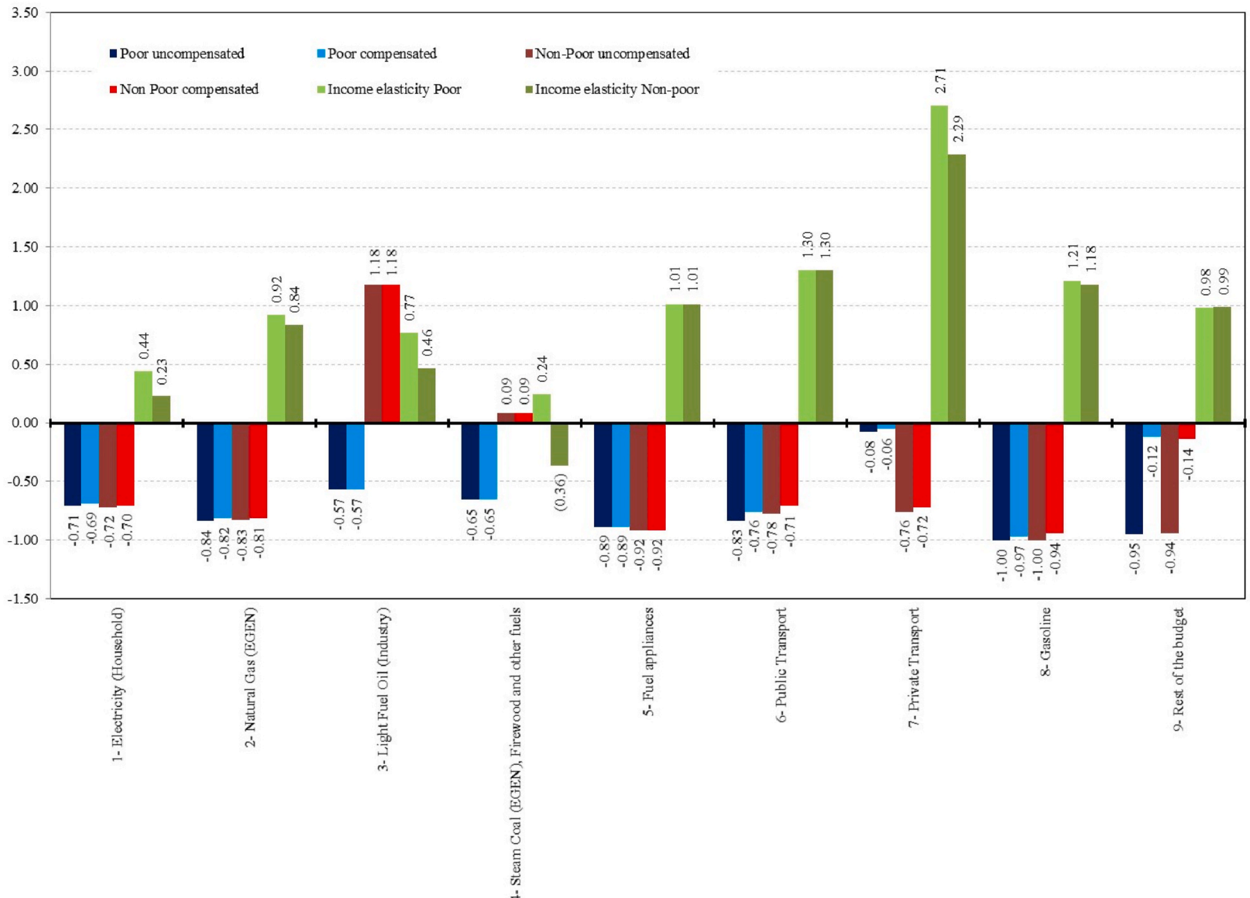
$$w_i = \alpha_i + \sum_{j=0}^{n} \gamma_{ij} \ln(p) + \beta_i \ln\left(\frac{m}{a(p)}\right) + \frac{\lambda_i}{b(p)} \left[\ln\left(\frac{m}{a(p)}\right) \right]^2$$

noting the sum of shares must equal one, $\sum_{i=0}^{n} w_i = 1$.

Next, we incorporate the poverty variable and other socioeconomic characteristics denoted as z. Then, the household expenditure function can then be written as

$$e(p,z,u) = \overline{m}_0(z) \times \varphi(p,z,u)$$

where $\overline{m}_0(z) = 1 + \rho \acute{z}$ measures the increments in the expenditure of the household as a function of socioeconomic characteristics, such as poverty level. The second term controls for consumption patterns, such



Graph 4. Price and income elasticities (QUAIDS) 1992–2014 (ex-2004).

that

$$\ln \varphi(p,z,u) = \frac{\prod_{j=0}^{n} \lambda_j \ln p_j^{\beta_j}\left(\prod_{j=0}^{n} p_j^{\eta_j \acute{z}} - 1\right)}{\frac{1}{u} - \prod_{j=0}^{n} \lambda_j \ln p_j}.$$

The jth column of parameters is η_j and the equation of expenditure for each good is:

$$w_i = \alpha_i + \sum_{j=0}^{n} \gamma_{ij} \ln p_j + \left(\beta_i + \eta_j \acute{z}\right) \ln\left\{\frac{m}{\overline{m}_0(z)a(p)}\right\} + \frac{\lambda_i}{b(p)c(p,z)}\left[\ln\left\{\frac{m}{\overline{m}_0(z)a(p)}\right\}\right]^2$$

with $c(p,z) = \prod_{j=0}^{n} p_j^{\eta_j \acute{z}}$, and $\sum_{j=0}^{n} \eta_{rj} = 0$, for $i = 0, 1, \ldots, n$.

Elasticities are estimated assuming symmetry in the Slutsky equation, and where the non-compensated elasticities of good i with respect to a change in price j are

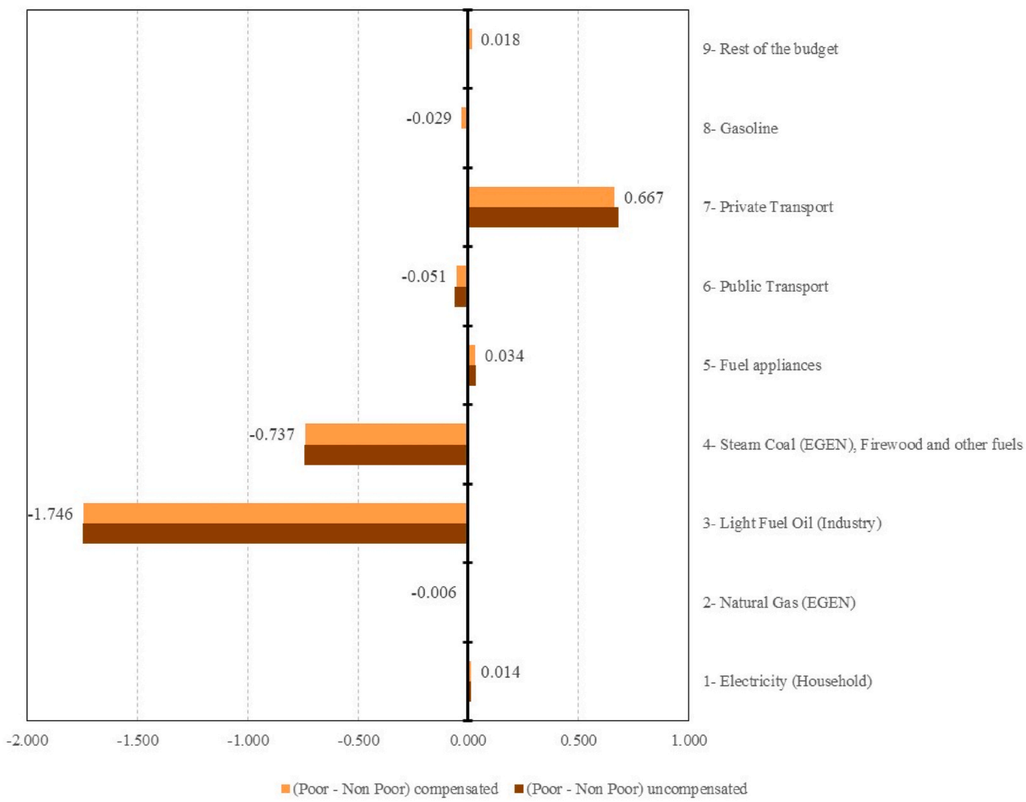
$$\varepsilon_{ij} = \delta_{ij} + \frac{1}{w_i}\left\{\begin{array}{l} \gamma_{ij} - \left[\beta_i + \eta_j \acute{z} + \frac{2\lambda_i}{b(p)c(p,z)}\left(\ln\left\{\frac{m}{\overline{m}_0(z)a(p)}\right\}\right)\right] \times \left(\alpha_j + \sum_{j=0}^{n} \gamma_{ij} \ln p_j\right) \\ - \frac{(\beta_i + \eta_j \acute{z})\lambda_i}{b(p)c(p,z)}\left[\ln\left(\frac{m}{\overline{m}_0(z)a(p)}\right)\right]^2 \end{array}\right\},$$

and the compensated elasticities are $\varepsilon_{ij}^c = \varepsilon_{ij} + \mu_i w_j$ where μ_i denotes the income elasticity of good i. Both non-compensated and compensated elasticities are reported below.

In order to assess the stability of the energy elasticities to the inclusion of different demand determinants, several models are estimated. In addition to QUAIDS, we estimate the elasticities using OLS for each good separately, then a system of equations with SUR and AIDS. This enables a comparison of the results from QUAIDS, OLS, SUR and AIDS.

4. Data

We use the national survey of income and expenditure of households (ENIGH) conducted by the national statistical office (INEGI) covering the years 1992 through 2014. The survey is biannual since 1992, has a consistent methodology from 1992 to 2014, and includes an extra survey for the year 2005. Importantly, the survey does not interview the same households over time, but it is representative at national, regional, and rural/urban strata. Beginning in 2008, the survey became



Graph 5. Difference between Poor and Non-poor elasticities (QUAIDS) (ex-2004).

Table 5
Summary or price elasticities using QUAIDS, AIDS, SUREG and OLS.

	Min ε	Max ε	Min (estimator detail)	Max (estimator detail)
1- Electricity (Household)	−3.19	−0.21	OLS (1992–2014 ex-2004)	SUR (1992–2014 ex-2004)
2- Natural Gas (EGEN)	−2.96	−0.76	OLS (1992–2014 ex-2004)	SUR (1992–2014 ex-2004)
3- Light Fuel Oil (Industry)[a]	−6.14	1.18	OLS (1992–2014 ex-2004)	QUAIDS Non-Poor uncompensated (1992–2014 ex-2004)
4- Steam Coal (EGEN), Firewood and other fuels	−0.72	0.09	QUAIDS Non-Poor uncompensated (1992–2014)	QUAIDS Non-Poor uncompensated (1992–2014 ex-2004)
5- Fuel appliances[a]	−0.93	−0.77	AIDS Non-Poor uncompensated (1992–2004)	OLS (1992–2014 ex-2004)
6- Public Transport	−0.85	−0.63	QUAIDS Poor uncompensated (1992–2014)	SUR (1992–2014)
7- Private Transport	−0.79	−0.06	QUAIDS Non-Poor uncompensated (1992–2014)	QUAIDS Poor compensated (1992–2014 ex-2004)
8- Gasoline	−1.01	−0.89	AIDS Poor uncompensated (1992–2014 ex-2004)	AIDS Poor compensated (1992–2014)
9- Rest of the budget	−0.98	−0.10	OLS (1992–2014)	QUAIDS Poor compensated (1992–2014)

[a] Not statistically significant.
Source: Authors' calculations.

representative at the state level for household expenditures to calculate the official poverty line. It is worth noting that in 2016 the survey methodology changed (CONEVAL, 2018) and the statistical office allows users access to the new series from 2016, as well as the previous series, but the methodologies are not consistent pre and post 2016.

The survey collects information of expenditure and income of each respondent, their socioeconomic characteristics, and their assets. We code all expenditures on services and goods across years to make them comparable, Table A1 in the Appendix, shows the codes for fuels as an example. A common feature in energy consumption is that respondents report expenditure but price and quantity consumed are absent (Deaton, 1997). As such, we use unit prices from the International Energy Agency (IEA) for the period 1992 to 2014 (see Graph 2). The prices for electricity, gasoline and steam coal tend to increase throughout the period, whereas light fuel oil and natural gas oscillate from 2008. As discussed by (Rosas-Flores et al., 2017), energy prices faced by households in Mexico are set by the government without the option to vote against these decisions, and they are highly subsidized, therefore in most of the

Table 6
Simulation with different price changes, using the estimated QUAIDS model.

Good	Average Expenses predicted by the model (MX Pesos)					
	Household type	At original prices	10% price increase in all goods	10% price increase in electricity	10% price increase in gas	10% price decrease in gasoline
Electricity	Non-Poor	285.69	299.48	**294.45**	181.21	287.04
Electricity	Poor	129.21	134.88	**133.21**	77.25	129.93
Gas	Non-Poor	213.45	216.94	218.07	**151.36**	211.79
Gas	Poor	104.02	105.15	106.01	**75.17**	103.42
LFO[a]	Non-Poor	4.14	4.55	4.50	1.22	4.11
LFO[a]	Poor	3.14	3.43	3.38	0.98	3.12
Carbon, Wood, Other fuels	Non-Poor	32.54	34.06	32.83	28.82	32.46
Carbon, Wood, Other fuels	Poor	27.47	28.63	27.69	24.58	27.41
Fuel appliances	Non-Poor	14.03	13.99	14.00	14.45	14.13
Fuel appliances	Poor	4.00	3.97	3.99	4.18	4.05
Public Transport	Non-Poor	626.05	616.85	625.94	626.31	626.10
Public Transport	Poor	300.59	295.99	300.39	302.98	301.10
Private Transport	Non-Poor	277.77	264.96	276.37	297.12	280.83
Private Transport	Poor	67.94	64.49	67.59	73.54	68.73
Gasoline, diesel or gas	Non-Poor	530.04	520.75	527.71	564.10	**530.00**
Gasoline, diesel or gas	Poor	125.99	122.66	125.23	137.29	**126.01**
Rest of the expenses	Non-Poor	8977.34	8986.73	8964.93	9161.47	8974.32
Rest of the expenses	Poor	3799.17	3806.11	3794.04	3874.77	3797.09
			Change in Average Expenses			
			10% price increase in all goods	10% price increase in electricity	10% price increase in gas	10% price decrease in gasoline
Electricity	Non-Poor		4.82%	**3.06%**	−36.57%	0.47%
Electricity	Poor		4.39%	**3.09%**	−40.21%	0.56%
Gas	Non-Poor		1.63%	2.16%	**−29.09%**	−0.78%
Gas	Poor		1.09%	1.92%	**−27.74%**	−0.58%
LFO[a]	Non-Poor		9.87%	8.61%	−70.63%	−0.79%
LFO[a]	Poor		9.10%	7.51%	−68.96%	−0.78%
Carbon, Wood, Other fuels	Non-Poor		4.69%	0.91%	−11.43%	−0.23%
Carbon, Wood, Other fuels	Poor		4.21%	0.78%	−10.53%	−0.21%
Fuel appliances	Non-Poor		−0.26%	−0.20%	3.02%	0.71%
Fuel appliances	Poor		−0.78%	−0.28%	4.33%	1.10%
Public Transport	Non-Poor		−1.47%	−0.02%	0.04%	0.01%
Public Transport	Poor		−1.53%	−0.07%	0.79%	0.17%
Private Transport	Non-Poor		−4.61%	−0.50%	6.97%	1.10%
Private Transport	Poor		−5.08%	−0.52%	8.24%	1.16%
Gasoline, diesel or gas	Non-Poor		−1.75%	−0.44%	6.43%	**−0.01%**
Gasoline, diesel or gas	Poor		−2.64%	−0.61%	8.97%	**0.02%**
Rest of the expenses	Non-Poor		0.10%	−0.14%	2.05%	−0.03%
Rest of the expenses	Poor		0.18%	−0.13%	1.99%	−0.05%

[a] Note: LFO is not statistically significant.
Source: Authors' calculations.

cases the reference price is below the international price and does not reflect marginal cost.[3] We will return to this point when discussing the results.

We use the official definition of income poverty, which counts as poor all households whose income is not sufficient to buy the collective of the food basket, education, health, transport, housing and clothing, referred to as Patrimony poverty (CONEVAL, 2009). This accounts for around 50% of the population of Mexico in the period of analysis. Table 2 shows that the number of poor people has increase from 46.1 million to 66.1, and in percentage terms, poverty has oscillated but in 2014 it was 55.1% compared to 53.1% in 1992.

When calculating the expenditure share for different fuels over time, we observe that the expenditures shares for poor and non-poor households for the year 2004 appear to be an outlier, even when accounting for changes in potential explanatory factors such as price and income, so we exclude the survey data for that year given the estimations where unstable, even when we split the periods (see Graph 3). Luckily, an extra survey for the year 2005 was done by the National Statistical Office and we can observe in the same graph that the 2005 survey is more consistent with the rest of the surveys.

We also test whether the expenditure behavior in the different fuels was the same for poor and non-poor households; the results show they are different. Table 3 indicates that the highest difference in budget shares between poor and non-poor are for gasoline and public and private transport. This can be attributed to differences in asset ownership across non-poor and poor households – non-poor households tend to own private cars and pay for gasoline, while poor households have a higher propensity to use public transport. The expenditure in steam coal and firewood is higher among poor households, which likely reflects a preference for cleaner fuels that can be more readily accessed with higher wealth.

The important characteristic of the Banks et al. (1997) model is that it allows the inclusion of socioeconomic characteristics in the demand

[3] The Federal Commission of Electricity in Mexico, charges flexible tariffs for households, the pricing blocks depend on the consumption quantities, the geographical area, the temperatures, the subsidies for summer and winter, and households do not really know what they will paid each month. The survey reports the consumption paid in monetary terms, and we use average prices to compute the elasticities.

system, which can more succinctly account for factors that impact revealed preference. Therefore, apart from the poverty variable, we control for household size, number of adults in a household, geographic characteristics (such as whether the household is in an urban or rural area), average latitude and altitude of the municipality where the household is located, as well as the mean temperature and rain. All of these can influence the energy use of households as they impact to different degrees the demand for energy services by individuals within a given household. For example, northern urban areas are more equipped with electric A/C and heating systems, while households in rural areas tend to heat with fuel oil and firewood. Households in rural areas also use more private transport fueled with diesel, while households in urban areas tend to use more cars with gasoline. As we add control variables to the analysis, higher computational power is needed for each estimation as we have 13 biannual surveys that are pooled and estimated independently (summary statistics are in Table A2 of the Appendix).

5. Estimation results

To investigate robustness of the elasticity estimates, we use different periods and different methods, then test for significance. All estimation results are available upon request. The results include estimation of QUAIDS for (i) the entire period spanning 1992 to 2014, year-by-year and also pooled, (ii) the entire period excluding 2004 (which is a data outlier in prices and expenditures), (iii) the period spanning 1992 to 2006 excluding 2004, and (iv) the period 2008 to 2014. The most stable elasticities are shown in Table 4, and the estimated coefficients are given in Table A3 of the Appendix. All constants, α_i, linear terms, β_i, and own price terms, γ_{ii}, are statistically significant, except for light fuel oil (β_{LFO}, γ_{LFO}). The quadratic terms, λ_i, are statistically significant for electricity, natural gas and public transport. With respect to the coefficients of social variables by good, η_j, the results highlight that poverty is significant for all goods except light fuel oil. Being in a rural or urban area also influences elasticity, as does household size and adult members in the household. The altitude, latitude, rain and temperature influence most of the fuel demands.

Several of the estimated coefficients, although similar, are actually different at the 3rd significant digit, which is not evident in Table 4. The price elasticities for light fuel oil and fuel appliances (the latter of which includes electric stoves) are not statistically significant. The price elasticities of steam coal and private transport demands have the greatest differences between poor and non-poor households. In the case of income elasticities, the parameter estimate for steam coal indicates it is an inferior good. The income elasticity of fuel appliances, transport and gasoline is elastic, in contrast with electricity, natural gas and light fuel oil which are inelastic (see Table 4 and Graph 4) (Graph 5).

By comparison, the estimated price elasticities of electricity, natural gas and gasoline using AIDS without differencing poor from non-poor households (similar to the approach taken in Rosas et al. (2017)), reveals compensated elasticities of −0.61, −0.34, and −0.72, respectively, and non-compensated elasticites of −0.64, −0.36, and −0.75, respectively. Table 4 shows that the elasticies for poor and non-poor households, both compensated and non-compensated, are all higher in absolute terms. Moreover, the parameter estimates reveal inelastic demands, except for the case of gasoline use in non-poor households. The difference in the elasticities of electricity and natural gas can be explained by the quadratic term in the QUAIDS estimation that is statistically significant. Regarding the difference in the estimated elasticities for gasoline across models, as indicated in Table A1 in the Appendix, gasoline was reported as one good in the survey from 1992 to 2005, but was split into three different categories in 2006. Rosas et al. (2017) do not specify why they report only gasoline using a data from 1994 to 2010, although they found it to be inelastic as well.

In order to check stability in the calculations, in the current analysis, elasticities were also estimated using AIDS, SUR and OLS for the various time periods, both with and without data for 2004 included. The minimum and maximum price elasticities are given in Table 5. We see from the estimates that there does not appear to be a consistent bias presented by any single estimator, although the OLS estimates tend to be the dominant source of minimum estimated elasticities across the models. This table is revealing because the systems estimators yield price elasticities that are inelastic.

6. Price simulations

In the data section we explained that retail energy prices in Mexico are set by the government rather than the market, they are usually subsidized, and households pay a price below the international reference price. In Mexico there has been a strong policy to subsidize fossil fuels. As such, the new climate change law is incompatible with the current fiscal and energy reforms because the price of renewable energies are more expensive compared to the existing prices of fossil fuels and electricity, given the lack of fiscal incentives and investments in renewables (see Ortega Diaz and Casamadrid Gutiérrez (2018)).

Using the coefficients of the QUAIDs model of Table A3, we conducted four simulations of price changes and predicted the new budgets shares and expenditures, keeping the household budget fixed. In the first simulation, we increase the prices of all goods by 10% to simulate how households would react in the case of an exogenous, homogeneous shock. In the second simulation, the price of electricity is increased by 10% while all other prices are unchanged. In the third simulation, there is a 10% increase in the price of natural gas, and in the fourth simulation, there is a 10% increase in the price of gasoline. In all simulations, it is important to remember that the cross-price elasticities have an influence on outcome also.[4]

Table 6 shows that a 10% increase in all prices will have a similar but differentiated effect between non-poor and poor households as households reshuffle expenditures in accordance with the shock. The 10% shock has the effect of increasing expenditures on electricity (4.82%, 4.39%), natural gas (1.63%, 1.09%), low-cost fuels like wood (4.69%, 4.21%), but reducing expenditures in public transport (−1.47%, −1.53%), private transport (−4.61%, −5.08%) and gasoline (−1.75%, -2.64%), for poor and non-poor households, respectively.

A 10% shock to the price of electricity indicates that both types of households increase their expenditure in electricity, natural gas and carbon, wood and other fuels, but cut expenses for transport and transport fuels. Recall, the shift is in expenditures, and price inelastic demands will tend to see quantities affected very little when price rises. This has a concomitant impact on the household budget that will force adjustments in other expenditures. As such, these results are driven by the estimated cross elasticities, where electricity and gas are complements, but are substitutes with gasoline. Notably, this effect was also found by Rosas et al. (2017).

The third simulation considers an increase of 10% in the price of the natural gas, and shows a strong reaction in both types of households. Each highly reduces their consumption and hence expenditures on electricity (−36.57%, −40.21%) and electricity (−29.09%, −27.74%), while increasing their expenditure shares in public transport (0.04%, 0.79%), private transport (6.97%, 8.24%) and gasoline (6.43%, 8.97%). The shock to natural gas prices has regressive effects in electricity as poor households must reduce their expenditures to cope with the resulting budget shortfalls. In other words, the own and cross-price elasticities reveal sizeable impacts on expenditure patterns.

The last simulation is of a 10% decrease in the price of gasoline. In this case, the effect for all expenditures is less than a 1.2%, with expenditures on electricity increasing (0.47%, 0.56%), natural gas decreasing (−0.78%, −0.58%), carbon, wood and other fuels decreasing (−0.23%, −0.21%), and public and private transport both increasing. Gasoline expenditures are affected only minimally (−0.01%, 0.02%),

[4] They are available on request.

with differences in direction of influence across poor and non-poor households.

7. Conclusion and policy implications

Using household survey data for Mexico spanning the period 1992 to 2014, we estimated the price and income elasticities for six fuels and two transport services using the QUAIDS methodology. Our results complement those of Bacon et al. (2010), whose work points to the usefulness of elasticities in forming public policy regarding taxes and subsidies for fuels across different income levels.

The estimated elasticities indicate that the price elasticity of demand for fuels is generally inelastic, which is consistent with a broad set of previous literature. The findings reveal that households do not tend to alter consumption by much when price increases, which supports the notion that energy goods are a necessity. Therefore, in a case where price increases, households will tend to devote a higher fraction of total expenditures on the necessity goods while cutting expenditures shares of other things. We also find that income elasticity for non-transport fuels is inelastic, but elastic for transport services and fuels. This indicates that consumers tend to adjust to changes in income by adjusting transportation activities the greatest. Finally, our results indicate that poor and non-poor household respond differently to steam coal prices, which seems to be an inferior good because the higher income households tend to use less of the fuel for heating or cooking.

The range of estimated elasticities seem plausible, and complement those estimated by Rosas et al. (2007), with the advantage that we account for the quadratic terms (which are statistically significant), and distinguish between poor and non-poor households over a longer time span. Once households have reached a saturation point – or the basic energy needs for cooking, heating and transport have been sated – their consumption will not increase at the same pace with income. We see that across time the expenditure shares on fuel and transport do not surpass 18% of the household budget. In fact, it is approximately 10% for transportation and 7% for non-transport fuels, which is analogous to what Bacon et al. (2010) found for several developing countries.

In the context of energy poverty – where energy poverty is loosely defined as a lack of access to modern energy services – our results indicate that the inability to afford energy services even when adequate infrastructure exists can be exacerbated when prices increase. This, in turn, can have deleterious impacts on household well-being through three sources: (1) reduce disposable income due to greater fraction of expenditures being allocated to energy, (2) worsen respiratory health in the household due to the use of lower cost fuel substitutes such as coal and firewood, and (3) increase local air pollution due to an expanded prevalence of low quality transportation services.

Notably, the household survey data indicate that overall expenditure patterns on fuels between poor and non-poor households are similar, but the amounts spent on different fuels are statistically different. Higher differences are observed in the amount spent for coal and firewood, public/private transport services and gasoline, where coal and firewood expenditure shares are higher for poor households, while transport services and gasoline expenditure shares are higher for non-poor households. These results indicate the coal and firewood are inferior goods, whereas transportation services and transport fuels are not.

Four different price shock simulations were conducted using the estimated parameters in QUAIDS system. In the first three, we introduce a 10% increase in the price of all goods, electricity, and natural gas, respectively. In the fourth, we decrease the price of gasoline by 10%. This allows us to determine the impact of the shock to expenditures while keeping the household budget fixed. The simulated results are congruent with the experiences of Mexican households in the last several years. With respect to gasoline, since 2006 different presidential administrations have been dealing with reducing the gasoline subsidy, which tends to act as a shock to retail gasoline prices. But the current administration has recently reversed course and increased the subsidy, but, interestingly, our simulations indicate that this has almost no effect on gasoline expenditure, and a very low effect on transport services consumption. Knowing this is informative, and it can allow for better coordination of fiscal and environmental policies, particularly if one aim is to reduce incentives for fossil fuel use while increasing incentives on other forms of energy.

In closing, our results support the argument that household price elasticities should be considered when defining a schedule of taxes/subsidies for different household types so that concerns about the affordability of energy services are allayed. This is especially poignant given that fuel prices in Mexico have generally increased. These elasticities would be a tool to calculate whether changes in taxes or subsidies would be progressive or regressive. Our results are the first elasticities, to our knowledge, that are calculated for poor and non-poor households using official poverty lines.

CRediT authorship contribution statement

Araceli Ortega Díaz: Conceptualization, Methodology, Software, Data curation, Writing - original draft, preparation, Investigation, Software, Writing - review & editing. **Kenneth B. Medlock:** Supervision, Validation, Writing - review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.enpol.2021.112132.

APPENDIX

Table A1
Coding of fuels and fuel commodities reported in the household surveys (name code in Spanish)

Goods	1992–98	2000	2002	2004	2005	2006	2008	2010	2012	2014
Fuels										
Gasoline, diesel o gas	Gasolina (F006)	Gasolina, diesel o gas (F007)	Gasolina, diesel o gas (F010)	Gasolina, diesel o gas (F010)	Gasolina, diesel o gas (F010)	Gasolina, diesel o gas (F010)	Gasolina magna (F010) Gasolina premium (F011) Diesel y gas (F012)	Gasolina magna (F007) Gasolina premium (F008) Diesel y gas (F009)	Gasolina magna (F007) Gasolina premium (F008) Diesel y gas (F009)	Gasolina magna (F007) Gasolina premium (F008) Diesel y gas (F009)
Electricity and fuels										
Electric Energy	Energía Eléctrica (G022)	Energía Eléctrica (G026)	Energía Eléctrica (G003,G010,G014, G019,G025,G029, G035)	Energía Eléctrica (G008)	Energía Eléctrica (G008)	Energía Eléctrica (G008)	Energía Eléctrica (G008)	Energía Eléctrica (R001)	Energía Eléctrica (R001)	Energía Eléctrica (R001)
Gas	Gas (G023)	Gas (G027)	Gas (G004,G011,G015, G020,G026,G030, G036)	Gas (G009)	Gas (G009)	Gas LP (G009) Gas natural (G010)	Gas LP (G009) Gas natural (G010)	Gas LP (G009) Gas natural (R003)	Gas LP (G009) Gas natural (R003)	Gas LP (G009) Gas natural (R003)
Fuel oil	Petróleo (G024)	Petróleo (G028)	Petróleo (G041)	Petróleo (G023)	Petróleo (G023)	Petróleo (G024)	Petróleo (G016)	Petróleo (G010)	Petróleo (G010)	Petróleo (G010)
Carbon	Carbón (G025)	Carbón (G029)	Carbón (G043)	Carbón (G025)	Carbón (G025)	Carbón (G026)	Carbón (G018)	Carbón (G012)	Carbón (G012)	Carbón (G012)
Firewood	Leña (G026)	Leña (G030)	Leña (G044)	Leña (G026)	Leña (G026)	Leña (G027)	Leña (G019)	Leña (G013)	Leña (G013)	Leña (G013)
Other Fuels	Combustible para calentar (G027)	Combustible para calentar (G031)	Combustible para calentar (G045)	Combustible para calentar (G027)	Combustible para calentar (G027)	Combustible para calentar (G028)	Combustible para calentar (G020)	Combustible para calentar (G014)	Combustible para calentar (G014)	Combustible para calentar (G014)
			Diesel (G042)	Diesel (G024)	Diesel (G024)	Diesel (G025)	Diesel (G017)	Diesel (G011)	Diesel (G011)	Diesel (G011)
	Velas y veladoras (G028)	Velas y veladoras (G032)	Velas y veladoras (G046)	Velas y veladoras (G028)	Velas y veladoras (G028)	Velas y veladoras (G029)	Velas y veladoras (G021)	Velas y veladoras (G015)	Velas y veladoras (G015)	Velas y veladoras (G015)
	Otros combustibles (G029)	Otros combustibles (G033)	Otros combustibles (G047)	Otros combustibles (G029)	Otros combustibles (G029)	Otros combustibles (G030)	Otros combustibles (G022)	Otros combustibles (G016)	Otros combustibles (G016)	Otros combustibles (G016)

Goods	1992–94	1996–98	2000	2002–2014
Fuel Appliances	Estufa de gas (K005)	Estufa de gas (K006)		Estufa de gas (K007)
	Estufa de otros combustibles (K006)	Estufa de otros combustibles (K007)		Estufa de otros combustibles (K008)
	Calentador de gas (K014)	Calentador de gas (K015)		Calentador de gas (K017)
	Calentador de otros combustibles (K015)	Calentador de otros combustibles (K016)		Calentador de otros combustibles (K018)
	Lámparas eléctricas (K016)	Lámparas eléctricas (K017)		Lámparas eléctricas (K019)
	Lámparas de otros combustibles (K017)	Lámparas de otros combustibles (K018)		Lámparas de otros combustibles (K020)
	–	–	Tanque de gas e instalación (K019)	Tanque de gas e instalación (K021)
Public Transport	Transporte foráneo (M001)			
	Transporte ferroviario (M002)			
	Transporte aéreo (M003)			
	Servios de carga y mudanza (M004)			
	Cuotas de autopista (M005)			
	Otros: lanchas, barcos, etc. (M006)			
Private Transport	Automóvil y/o guayin (M007)			
	Camioneta (pick up) (M008)			
	Motoneta y motocicleta (M009)			
	Bicicleta (M010)			
	Otros: remolque, lancha, etc (M011)			
	Llantas (M012)			
	Acumulador (M013)			
	Otras refacciones y accesorios (M014)			
		Partes de vehículos (M015)		
		Accesorios (M016)		
	Servicio de afinación, alineación y balanceo (M015)	Servicio de afinación, alineación y balanceo (M017)		
	Otros servicios (M016)	Otros servicios (M018)		

Source: authors own source using ENIGH.

Table A2
Summary Statistics 1992 to 2014

PERIOD 1992–2014																
	All observations						Non-poor					Poor				
	Variable	Obs	Mean	Std. Dev.	Min	Max	Obs	Mean	Std. Dev.	Min	Max	Obs	Mean	Std. Dev.	Min	Max
Expenditure percentages	w_ele	225,412	0.031	0.044	0.000	0.943	122,648	0.031	0.044	0.000	0.941	102,764	0.031	0.044	0.000	0.943
	w_gas	225,412	0.023	0.035	0.000	0.939	122,648	0.023	0.032	0.000	0.846	102,764	0.023	0.038	0.000	0.939
	w_oil	225,412	0.000	0.006	0.000	0.844	122,648	0.000	0.004	0.000	0.556	102,764	0.001	0.008	0.000	0.844
	w_carb	225,412	0.004	0.020	0.000	0.854	122,648	0.002	0.012	0.000	0.676	102,764	0.007	0.026	0.000	0.854
	w_app	225,412	0.001	0.009	0.000	0.741	122,648	0.001	0.010	0.000	0.741	102,764	0.001	0.009	0.000	0.534
	w_pub_tra	225,412	0.057	0.078	0.000	1.000	122,648	0.054	0.074	0.000	1.000	102,764	0.062	0.083	0.000	1.000
	w_pri_tra	225,412	0.014	0.058	0.000	0.914	122,648	0.021	0.071	0.000	0.867	102,764	0.005	0.035	0.000	0.914
	w_gasoline	225,412	0.032	0.060	0.000	0.855	122,648	0.043	0.065	0.000	0.855	102,764	0.019	0.050	0.000	0.824
	w_rest	225,412	0.837	0.118	0.000	1.000	122,648	0.825	0.121	0.000	1.000	102,764	0.852	0.114	0.000	1.000
Real Prices (2010 = 100)	pcalc_ele	225,412	1172.87	209.24	13.23	1356.61	122,648	1179.31	217.81	13.23	1356.61	102,764	1165.18	198.25	13.23	1356.61
	pcalc_gas	225,412	273.05	126.60	3.47	456.49	122,648	283.08	127.83	3.47	456.49	102,764	261.07	124.05	3.47	456.49
	pcalc_oil	225,412	4.29	2.10	0.03	8.30	122,648	4.38	2.05	0.03	8.30	102,764	4.19	2.16	0.03	8.30
	pcalc_carb	225,412	167.51	233.50	0.03	5178.21	122,648	166.60	236.39	0.03	5178.21	102,764	168.60	230.01	0.03	5178.21
	pcalc_app	225,412	685.88	1258.43	0.00	26,439.32	122,648	739.39	1340.71	0.00	26,439.32	102,764	622.01	1149.32	0.00	26,439.32
	pcalc_pub_tra	225,412	378.20	1575.36	0.00	127,214.00	122,648	471.75	1946.42	0.00	127,214.00	102,764	266.55	948.27	0.01	127,214.00
	pcalc_pri_tra	225,412	1636.72	11,024.19	0.00	1,259,025.00	122,648	1854.58	12,319.06	0.00	1,259,025.00	102,764	1376.70	9237.66	0.00	1,259,025.00
	pcalc_gasoline	225,412	27.78	184.63	0.08	15,618.42	122,648	31.73	214.75	0.08	15,618.42	102,764	23.07	140.33	0.08	8817.09
	pcalc_rest	225,412	132.14	234.78	0.01	26,954.75	122,648	178.06	290.67	0.01	26,954.75	102,764	77.34	120.62	0.17	12,172.08
Real Expenditure	g_ele	225,412	227.86	450.39	0.00	38,380.69	122,648	309.97	570.19	0.00	38,380.69	102,764	129.86	198.22	0.00	9202.99
	g_gas	225,412	155.35	201.21	0.00	11,432.49	122,648	196.50	234.98	0.00	11,432.49	102,764	106.24	135.92	0.00	4232.75
	g_oil	225,412	0.73	9.64	0.00	1688.45	122,648	0.40	9.98	0.00	1688.45	102,764	1.12	9.19	0.00	633.97
	g_carb	225,412	16.26	66.66	0.00	5196.72	122,648	12.71	62.31	0.00	5196.72	102,764	20.50	71.28	0.00	4098.77
	g_app	225,412	9.46	80.93	0.00	4442.69	122,648	13.47	99.85	0.00	4442.69	102,764	4.66	49.22	0.00	2156.18
	g_pub_tra	225,412	419.92	717.87	0.00	78,585.27	122,648	508.23	858.44	0.00	78,585.27	102,764	314.53	480.06	0.00	9541.03
	g_pri_tra	225,412	292.09	2234.36	0.00	211,558.10	122,648	496.28	2971.58	0.00	211,558.10	102,764	48.38	550.20	0.00	62,057.17
	g_gasoline	225,412	347.21	727.56	0.00	36,645.50	122,648	546.75	896.91	0.00	36,645.50	102,764	109.05	311.07	0.00	8214.25
	g_rest	225,412	7973.11	11,651.07	0.00	755,388.60	122,648	10,812.01	14,107.30	0.00	755,388.60	102,764	4584.91	6256.14	0.00	590,241.20
	gt	225,412	9441.98	12,990.69	10.08	756,568.70	122,648	12,896.32	15,749.05	29.35	756,568.70	102,764	5319.24	6550.37	10.08	591,913.40
Demographics and controls	Poor = 1	225,412	0.46	0.50	–	1.00	122,648	–	–	–	–	102,764	1.00	–	1.00	1.00
	Rural = 1	225,412	0.39	0.49	–	1.00	122,648	0.30	0.46	–	1.00	102,764	0.49	0.50	–	1.00
	Hosehols size	225,412	4.13	2.09	1.00	43.00	122,648	3.51	1.75	1.00	21.00	102,764	4.87	2.21	1.00	43.00
	Adults	225,412	3.07	1.55	1.00	33.00	122,648	2.87	1.44	1.00	15.00	102,764	3.32	1.63	1.00	33.00
	altitud	223,501	1135.35	923.83	1.00	2840.00	122,009	1133.92	934.47	1.00	2840.00	101,492	1137.08	910.86	1.00	2840.00
	lenght	223,501	−99.98	5.69	−117.06	−86.75	122,009	−100.62	5.93	−117.06	−86.75	101,492	−99.20	5.28	−117.06	−86.75
	latitud	223,501	21.39	3.70	14.68	32.66	122,009	21.86	3.90	14.68	32.66	101,492	20.84	3.35	14.68	32.66
	mean temperature	225,360	20.23	22.56	8.00	613.00	122,627	19.81	20.55	8.00	613.00	102,733	20.73	24.74	8.00	613.00
	mean rain	225,360	957.93	601.71	23.50	4000.00	122,627	867.11	528.58	26.00	4000.00	102,733	1066.32	662.65	23.50	4000.00
	year	225,412	2004.40	5.93	1992.00	2013.00	122,648	2004.77	5.69	1992.00	2013.00	102,764	2003.96	6.18	1992.00	2013.00
	Poor = 45.6%															

Table A3
Estimated Coefficients of QUAIDS

	Parameter	Coefficient	
Constant terms α_i			
1- Electricity (Household)	alpha_1	−9.28E-02	***
2- Natural Gas (EGEN)	alpha_2	5.14E-02	***
3- Light Fuel Oil (Industry)	alpha_3	−2.09E-02	**
4- Steam Coal (EGEN), Firewood and other fuels	alpha_4	−3.62E-02	***
5- Fuel appliances	alpha_5	3.51E-03	*
6- Public Transport	alpha_6	5.85E-01	***
7- Private Transport	alpha_7	1.18E-01	***
8- Gasoline	alpha_8	1.06E-01	***
9- Rest of the budget	alpha_9	2.86E-01	***
Income term β_i			
1- Electricity (Household)	beta_1	3.23E-02	***
2- Natural Gas (EGEN)	beta_2	1.40E-02	***
3- Light Fuel Oil (Industry)	beta_3	−1.04E-03	
4- Steam Coal (EGEN), Firewood and other fuels	beta_4	−4.62E-03	***
5- Fuel appliances	beta_5	1.05E-03	*
6- Public Transport	beta_6	5.39E-02	**
7- Private Transport	beta_7	1.51E-02	**
8- Gasoline	beta_8	4.71E-02	***
9- Rest of the budget	beta_9	−1.58E-01	***
Prices (own and cross) term γ_{ij}			
1- Electricity (Household)	**gamma_1_1**	1.01E-02	***
	gamma_2_1	4.57E-03	***
	gamma_3_1	1.33E-03	*
	gamma_4_1	1.03E-03	***
	gamma_5_1	−4.25E-05	
	gamma_6_1	−3.27E-03	*
	gamma_7_1	−2.34E-03	***
	gamma_8_1	−2.70E-03	**
	gamma_9_1	−8.64E-03	***
2- Natural Gas (EGEN)	**gamma_2_2**	4.84E-03	***
	gamma_3_2	−1.07E-03	*
	gamma_4_2	−3.67E-04	***
	gamma_5_2	5.06E-06	
	gamma_6_2	6.34E-03	***
	gamma_7_2	−2.40E-04	
	gamma_8_2	1.29E-03	
	gamma_9_2	−1.54E-02	***
Prices (own and cross) term γ_{ij} (cont.)			
3- Light Fuel Oil (Industry)	**gamma_3_3**	3.90E-04	
	gamma_4_3	4.18E-05	
	gamma_5_3	−3.05E-05	
	gamma_6_3	−1.55E-03	**
	gamma_7_3	−2.44E-04	*
	gamma_8_3	−4.85E-05	
	gamma_9_3	1.18E-03	**
4- Steam Coal (EGEN), Firewood and other fuels	**gamma_4_4**	2.68E-03	***
	gamma_5_4	−6.52E-05	***
	gamma_6_4	−2.01E-03	***
	gamma_7_4	−5.87E-04	***
	gamma_8_4	−2.18E-04	
	gamma_9_4	−5.00E-04	
5- Fuel appliances	**gamma_5_5**	1.01E-04	
	gamma_6_5	2.77E-04	
	gamma_7_5	−2.58E-05	
	gamma_8_5	−8.06E-05	
	gamma_9_5	−1.38E-04	
6- Public Transport	gamma_6_6	6.40E-02	***
	gamma_7_6	4.19E-03	
	gamma_8_6	1.55E-03	
	gamma_9_6	−6.96E-02	***
7- Private Transport	gamma_7_7	6.71E-03	***
	gamma_8_7	−1.76E-03	***
	gamma_9_7	−5.71E-03	
8- Gasoline	gamma_8_8	8.75E-04	
	gamma_9_8	1.08E-03	
9- Rest of the budget	**gamma_9_9**	9.77E-02	**
Quadratic term λ_i			
1- Electricity (Household)	lambda_1	4.59E-04	***
2- Natural Gas (EGEN)	lambda_2	8.22E-04	***
3- Light Fuel Oil (Industry)	lambda_3	−7.49E-05	
4- Steam Coal (EGEN), Firewood and other fuels	lambda_4	−1.08E-05	
5- Fuel appliances	lambda_5	2.34E-05	
6- Public Transport	lambda_6	4.76E-03	***
7- Private Transport	lambda_7	−4.33E-04	

(*continued on next page*)

Table A3 (*continued*)

	Parameter	Coefficient	
8- Gasoline	lambda_8	−4.02E-04	
9- Rest of the budget	lambda_9	−5.14E-03	***

Social/Climate Variables own term

Param	Coef (b)		Param	Coef (b)	
rho_poblp3	1.86E+00		rho_l_altitud	7.19E-01	**
rho_rururb	−5.07E+01		rho_l_latitud	2.78E+01	
rho_lhhsize	1.04E+00		rho_l_tem_mean	−8.24E+00	**
rho_ladults	−1.80E+00	**	rho_l_rain_mean	4.34E+00	***
rho_l_longitud	−1.86E+00				

Social/Climate Variables by Good

Param	Coef (b)		ηj	Param	Coef (b)		ηj
eta_poblp3_1	7.09E-04	***	Poverty = = 1	eta_l_altitud_1	1.81E-04	***	Altitude
eta_poblp3_2	2.33E-04	***		eta_l_altitud_2	−1.31E-04	***	
eta_poblp3_3	3.16E-05			eta_l_altitud_3	1.67E-06		
eta_poblp3_4	−1.22E-04	***		eta_l_altitud_4	−3.46E-05	***	
eta_poblp3_5	2.83E-05	***		eta_l_altitud_5	−1.53E-06		
eta_poblp3_6	−4.52E-04	***		eta_l_altitud_6	1.15E-04	***	
eta_poblp3_7	1.10E-03	***		eta_l_altitud_7	1.01E-05		
eta_poblp3_8	1.85E-03	***		eta_l_altitud_8	3.30E-05		
eta_poblp3_9	−3.38E-03	***		eta_l_altitud_9	−1.73E-04	***	
eta_rururb_1	−1.85E-04		Rural = = 1	eta_l_latitud_1	−2.49E-03	***	Latitude
eta_rururb_2	1.56E-04	**		eta_l_latitud_2	1.14E-05		
eta_rururb_3	−1.48E-04	**		eta_l_latitud_3	−6.89E-05		
eta_rururb_4	−7.16E-04	***		eta_l_latitud_4	6.68E-04	***	
eta_rururb_5	−8.12E-06			eta_l_latitud_5	−6.29E-05	*	
eta_rururb_6	2.02E-03	***		eta_l_latitud_6	5.18E-03	***	
eta_rururb_7	9.56E-04	***		eta_l_latitud_7	−2.95E-03	***	
eta_rururb_8	8.95E-04	***		eta_l_latitud_8	−6.16E-03	***	
eta_rururb_9	−2.97E-03	***		eta_l_latitud_9	5.87E-03	***	
eta_lhhsize_1	5.13E-04	***	Household size	eta_l_tem_mean_1	−1.06E-03	***	Mean Temperature
eta_lhhsize_2	6.89E-04	***		eta_l_tem_mean_2	9.97E-04	***	
eta_lhhsize_3	−2.27E-05			eta_l_tem_mean_3	−5.67E-05	***	
eta_lhhsize_4	1.64E-04	***		eta_l_tem_mean_4	−6.12E-05		
eta_lhhsize_5	−1.34E-05	*		eta_l_tem_mean_5	−5.17E-05	***	
eta_lhhsize_6	1.67E-03	***		eta_l_tem_mean_6	2.64E-03	***	
eta_lhhsize_7	−1.65E-04	***		eta_l_tem_mean_7	1.99E-05		
eta_lhhsize_8	−1.10E-04			eta_l_tem_mean_8	3.86E-04	*	
eta_lhhsize_9	−2.73E-03	***		eta_l_tem_mean_9	−2.81E-03	***	

Social/Climate Variables by Good

Param	Coef (b)		ηj	Param	Coef (b)		ηj
eta_ladults_1	−1.06E-03	***	Number of adults	eta_l_rain_mean_1	5.02E-04	***	Mean rain
eta_ladults_2	−6.63E-04	***		eta_l_rain_mean_2	4.00E-04	***	
eta_ladults_3	−2.06E-05	*		eta_l_rain_mean_3	−6.54E-05	**	
eta_ladults_4	−1.33E-04	***		eta_l_rain_mean_4	−1.45E-04	***	
eta_ladults_5	3.39E-05	***		eta_l_rain_mean_5	−1.64E-06		
eta_ladults_6	−2.40E-03	***		eta_l_rain_mean_6	−2.16E-04	**	
eta_ladults_7	4.80E-04	***		eta_l_rain_mean_7	−1.63E-04	***	
eta_ladults_8	−4.05E-04	***		eta_l_rain_mean_8	−7.09E-05		
eta_ladults_9	4.17E-03	***		eta_l_rain_mean_9	−2.40E-04	**	
eta_l_longitud_1	−6.73E-03	***	Length	eta_l_longitud_6	5.11E-03	***	Length
eta_l_longitud_2	−1.45E-03	***		eta_l_longitud_7	1.26E-04		
eta_l_longitud_3	−1.88E-04	*		eta_l_longitud_8	−5.93E-03	***	
eta_l_longitud_4	2.32E-05			eta_l_longitud_9	9.09E-03	***	
eta_l_longitud_5	−4.65E-05						

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