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Xavier Labandeira
José M. Labeaga
Xiral López-Otero
Thomas Sterner

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Xavier Labandeira[a], José M. Labeaga[b], Xiral López-Otero[b], Thomas Sterner[c]

[a] Ecobas and Rede, Universidade de Vigo, Facultade de CC.EE, Campus As Lagoas s/n, 36310 Vigo, Spain, xavier@uvigo.gal

[b] Departamento de Teoría Económica y Economía Matemática, UNED, Senda del Rey 11, 28040 Madrid, Spain, jlabeaga@cee.uned.es; xiral@outlook.es

[c] Department of Economics, University of Gothenburg, Vasagatan 1, 41124 Gothenburg, Sweden, thomas.sterner@economics.gu.se

Abstract

The main aim of this paper is to analyze the different impacts of carbon taxation in Mexican households at different income levels. First, we estimate a household demand system for non-durable goods with special emphasis on energy-related goods. Then, we use the results to simulate the introduction of a carbon tax. We look at the potential to raise revenue with the aim of implementing different redistributive policies in order to address issues of inequality and poverty. Moreover, we evaluate the effects of carbon taxes on demand and emissions reduction.

Keywords: emissions; carbon taxation; distribution; poverty; Mexico

JEL Classification: D12; D31; H23; H31; Q48

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1. Introduction

Among the commitments of the Paris Agreement (UN, 2015), the signatory countries agreed to reduce their greenhouse gas emissions, translating this commitment into Nationally Determined Contributions (NDCs). Mexico commits unconditionally to reduce its greenhouse gas (GHG) emissions by 22 percent in 2030 compared to the baseline constructed in a baseline scenario estimated for 2013 (991MtCO_2e). In addition, conditional commitments would increase emissions mitigation to 36 percent in 2030 compared to the baseline scenario (Government of Mexico, 2020)[1]. Within Mexican GHG emissions, energy-related emissions stand out, accounting for 63.5 percent of gross GHG emissions and 87.5 percent of net emissions (including removals) in 2019 (SEMARNAT, 2022). It is therefore crucial, to achieve significant reductions in the coming years, to design and implement public policies particularly for the energy sector.

Mexico initiated an energy reform in December 2013 (see Álvarez and Valencia, 2015, SENER, 2015, Vargas, 2015), with the aim of substantially transforming the energy sector. This reform was far reaching by Mexican standards and entailed steps that were earlier considered unthinkable in Mexico such as the elimination of PEMEX's monopoly, as well as the modification of the mechanism for determining tax rates on gasoline (which often resulted in the tax actually being a subsidy), replacing it with fixed tax rates (see Muñoz, 2013). A carbon tax on fossil fuels was also introduced (albeit at too low a rate to trigger behavioural change) and the electricity sector was reformed to try to reduce its costs (see Husar and Kitt, 2016).

These steps were a radical departure with historical precedents in Mexico where politics has been heavily marked by a fierce nationalism that has its origins in the nationalisation of foreign oil companies by President Lázaro Cardenas in 1938. Since at least the 1970s Mexico turned into a major oil producer and exporter with profound effects on the structure of the Mexican economy which showed many of the signs of Dutch disease, (Guevara et al., 2022). During the last thirty years or more, Mexican development has been marked by a dominance of the petroleum sector, low domestic energy prices and the effects this has on (energy intense) technology choice and industrial structure (Sterner 1985, 1989). However, over time this strategy has led to problems such

[1] Fulfilling these commitments involves the international consolidation of technology transfer mechanisms, an international carbon trading price, carbon adjustment tariffs, technical cooperation, access to low-cost financial resources and technology transfer, all on a scale equivalent to the challenge of global climate change.

as the overvaluation of national currency and consequent problems of competitivity for non-petroleum sectors in the economy. Eventually Mexican exports of oil could not sustain the economy and furthermore the challenge of dealing with climate change and other factors have led to a change in policy.

Starting with the change of government in 2018, several measures were put in place however, with the aim of not increasing real energy prices, which limited the scope of the reforms. In particular, a new mechanism for residential electricity tariffs was established, so that they only adjust based on inflation and do so gradually during the year, as well as the so-called "fiscal stimulus", which is approved weekly and involves a reduction in the tax rate on fuels (see Government of Mexico, 2019). This fiscal stimulus initially involved reductions of between 20-40 percent in the tax rate on gasoline, although currently (week of 23-29 April 2022) the fiscal stimulus is 100 percent (SEGOB, 2022), which means that the tax on fuels is not applied. Furthermore, residential electricity tariffs are heavily subsidised, so that, on average, households pay only 46 percent of the total cost of the service (Hancevic et al., 2019), with electricity subsidies amounting to close to 0.3 percent of GDP (73 billion pesos in 2022, see Government of Mexico, 2022).

The 2013 energy reform also provided for the introduction of an emissions trading system. Mexico initiated a 36-month trial ETS programme in 2020, in which only installations operating in the energy and industry sectors whose annual emissions are at least 100,000 tonnes of direct CO_2 emissions participate (SEMARNAT, 2021). While the scheme is expected to be operational from 2023, there is uncertainty both on the timing of its introduction and on the emissions that will be covered by it. In this context of low taxation on energy products and uncertainty about the future emissions trading system, existing public policies are not incentivising energy savings and efficiency, so additional policies are needed to achieve significant reductions in carbon emissions to meet the Paris Agreement commitments. To this end, a carbon tax on energy products can be used at a sufficiently high level to achieve behavioural changes. This policy would also be complementary to the ETS, taxing sectors not covered by the ETS, as well as sectors included in the ETS until it becomes operational.

Therefore, our first objective in this paper is to simulate the environmental, revenue and distributional effects of a CO_2 emissions tax on the main Mexican energy products. Energy taxes have the capacity to generate a relevant volume of public revenue, sometimes at the cost of significant distributional impacts (see Gago et al., 2021). So, our second aim is to explore the introduction of compensatory mechanisms aimed to reduce poverty and inequality using the additional revenue generated by the new tax. Countries such as Mexico that show significant problems of poverty and inequality are unlikely to suffer significant distributional problems, but the extent of pre-existing poverty is so significant that the introduction of compensatory mechanisms may still be very important. Table 1 shows the poverty rate in 2018, i.e., the percentage of households living with less than 60 percent of median income (the poverty line as defined by Foster et al., 1984 or Heindl, 2015 among others) and using household expenditure as a proxy for income. We find that more than 23 per cent of Mexican households are in poverty, especially prominent in the south of the country (over 37 per cent of households in poverty) and in rural areas (almost 43 per cent). Regarding inequality, the Gini index shows that inequality is also higher in the south and in rural areas.

Table 1. Poverty rate and Gini index. 2018

	Total	North	Center	South	Urban	Rural
Poverty rate	23.84	21.15	19.25	37.22	17.98	43.19
Gini index	0.3711	0.3618	0.3594	0.3881	0.3547	0.3686

Note. The poverty rate is a percentage.
Source: Own elaboration with data from INEGI (2022b).

The academic literature on energy demand in Mexico has mainly focused on studying transport fuel demand (Bernt and Botero, 1985; Gately and Streifel, 1997; Eskeland and Feyzioglu, 1997a, 1997b; Galindo and Salinas, 1997; Haro and Ibarrola, 2000; Bauer et al., 2003; Reyes et al., 2010; Crôtte et al., 2010; Solís and Sheinbaum, 2013; Rodriguez-Oreggia and Yepez-Garcia, 2014; Fullerton et al., 2015; Akimaya and Dahl, 2018). Some papers have analysed electricity demand (Berndt and Samaniego, 1984; Chang and Martinez-Chambo, 2003; Salgado and Bernal, 2007; Hancevic and Lopez-Aguilar, 2019). Finally, we find studies on demand for various energy products (Sterner, 1989; Sheinbaum et al., 1996; Galindo, 2005).

On the other hand, the study of energy demand in the context of a complete demand system to analyse the effects of different policies affecting the energy sector has also received attention. Thus, Moshiri and Martinez (2018) study the effects of increases in the prices of energy products as a result of the 2014 Mexican energy reform; Renner et al. (2018) analyse the effects of the introduction of a carbon tax; Rosas-Flores et al. (2017) and Labeaga et al. (2021) study the impacts of the removal of energy subsidies and the introduction of carbon taxes; Ramírez et al. (2021) assess the impact of the 2014 Mexican energy reform; while Ortega and Medlock (2021) study the elasticity of demand for energy products as a function of household income level.

In addition to the aforementioned objectives, this paper aims to update the previous literature by using more recent data and simulating the impacts of introducing higher carbon prices that allow for a significant reduction in GHG emissions associated with energy consumption. To this end, the article is divided into five sections, including this introduction. Section 2 presents the data used and the methodology employed, while Section 3 reports the estimation results of the econometric model used. Section 4 presents the results of the simulations. The paper ends up with a summary and conclusion.

2. Data, variables, and demand system estimation for Mexico

2.1. Data and variables

We use microdata for the period 2006-2018 from the Encuesta Nacional de Ingresos y Gastos del Hogar (ENIGH) published by the Bureau of Statistics of Mexico (INEGI, Instituto Nacional de Estadística y Geografía). It is a biannual survey that uses face-to-face interviews to collect household budget data using stratified random sampling. The survey collects information on the value of household expenditures on different goods and services, providing detailed information on household and housing characteristics (see INEGI, 2022b). The initial sample size is 251,437 observations for all the pooled biannual cross-sections. The characteristics of the data as well as our own objectives make us select the sample as follows. We drop households where several families live, households with no expenditure on food, no expenditure on non-durable goods and households with no income, as well as first top and bottom percentiles of the distributions of total non-durable expenditure and income. This process reduces the sample by 21,142 observations. As we explain latter on, we do further sample selection in specific exercises.

We use the following categories of expenditure[2]: food at home, low octane gasoline (magna), high octane gasoline (premium), liquefied petroleum gases (LPG), electricity, and other non-durable goods[3]. Since our aim is to estimate a flexible Almost Ideal Demand System (either linear or quadratic), we calculate the expenditure shares for each commodity by dividing the expenditure on it by the total expenditure on non-durable goods in the household. As we will see later, in the specification of the demand model we include a wide set of sociodemographic variables whose definitions and descriptive statistic are in Table A1 in Annex A[4]. Thus, 31.7 percent of households live in the north of the country, while 44 percent live in the center and the remaining 24.3 percent in the south. Furthermore, 67.8 percent of households live in urban areas, 63.3 percent own a house without a mortgage, 12.7 percent rent the house where they live, 27 percent own a car, and 48 percent own a vehicle (car, van, pickup and/or motorbike). The household head is, on average 48.8 years old, 25.9 percent of household heads are women, and 10.2 percent report higher education level, while 26.6 percent report having only primary education.

We need price data with as much variation as possible to identify own and cross-price effects. We do have in the ENIGH survey information about the week where the interview took place. From this information, we create the variable month. The INEGI (2022c) considers the price indexes of different goods as well as the Retail Price Index (Índice Nacional de Precios al Consumo, INPC from now on) at monthly level in the cities[5]. INEGI provides price data for 46 cities for the whole

[2] All monetary variables, prices included, has been deflated using the regional Retail Price Index (RPI) to get variables in real terms.

[3] Other non-durable goods include non-alcoholic drinks, alcoholic drinks, tobacco, housing goods for cleaning and caring, goods for personal care, newspapers, stationery not for education, oils, lubricants and additives, candles and candlesticks, other fuels (carboard, paper for burning, etc.), medicines and healing materials, materials for dwelling repairing, photographic material, expenses on gifts to people outside de household (food, drinks and tobacco), diesel and gas for housing, petrol, diesel for transport, wood, fuel for heating and natural gas.

[4] Important variables for the purposes of this paper are geographical location of the household, both Entidad Federativa and municipality. We use the first five digits of variable “ubica_geo”, to get Entidad Federativa (two first digits) and municipality (three following digits). These two different location variables are listed (with assigned numbers) in INEGI (2022a). We check that Entidades Federativas are exactly what is usually named Mexican states.

[5] INEGI also provides information for the INPC for Entidades Federativas, but they do it only from 2018, which we introduce.

sample period[6], which we assign to Entidades Federativas[7].

We consider the monthly INPC for cities and we assign each household the price corresponding to the month when the survey was conducted. We consider the following nominal price indexes and the Retail Price Index (to construct and use real prices): food, electricity, LPG[8], magna gasoline, and premium gasoline. To complete a demand system, we add a category of other non-durable goods for which we do not have any information at city level (it implies that we cannot do the previous assignments to Entidades Federativas and municipalities), so the price of other non-durable goods is calculated as a weighted average of prices for alcoholic beverages and tobacco, detergents and similar products, drugs, personal care goods and services, newspapers, and other goods. The weights correspond to the share each household devote to each good[9]. Figure 1 shows some graphical evidence on the evolution of prices.

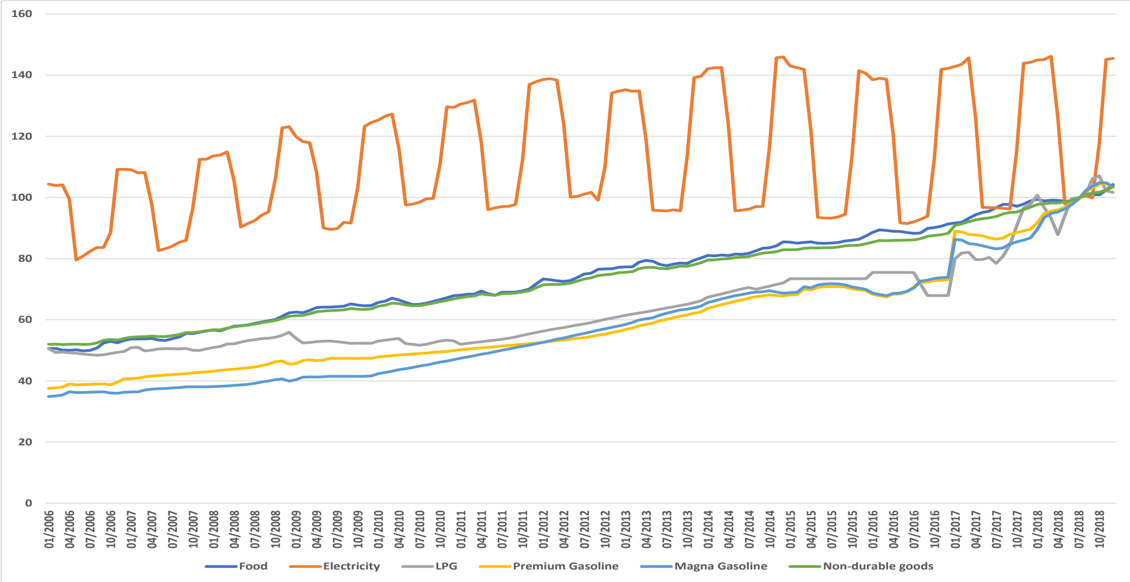
[6] Cities with price data by Entidad Federativa: Aguascalientes (Aguascalientes), Mexicali and Tijuana (Baja California), La Paz (Baja California Sur), Campeche (Campeche), Cd. Acuña, Monclova and Torreón (Coahulia de Zaragoza), Colima (Colima), Tapachula (Chiapas), Cd. Jiménez, Cd. Juárez and Chihuahua (Chihuahua), Ciudad de México (Distrito Federal), Durango (Durango), Cortazar and León (Guanajuato), Acapulco and Iguala (Guerrero), Tulancingo (Hidalgo), Guadalajara and Tepatitlán (Jalisco), Toluca (México), Jacona and Morelia (Michoacán de Ocampo), Cuernavaca (Morelos), Tepic (Nayarit), Monterrey (Nuevo León), Oaxaca and Tehuantepec (Oaxaca), Puebla (Puebla), Querétaro (Querétaro), Chetumal (Quintana Roo), San Luis Potosí (San Luis Potosí), Culiacán (Sinaloa), Hermosillo and Huatabampo (Sonora), Villahermosa (Tabasco), Matamoros and Tampico (Tamaulipas), Tlaxcala (Tlaxcala), Córdoba, San Andrés Tuxtla and Veracruz (Veracruz de Ignacio de la Llave), Mérida (Yucatán), and Fresnillo (Zacatecas).

[7] We assign prices to Entidades Federativas as follows: In those Entidades Federativas with only one city, we consider that the prices of the city correspond to the prices of the Entidad Federativa. If there is a Entidad Federativa with several cities, we calculate a population-weighted average of prices for the whole Entidad Federativa and assign these prices to the municipalities of the Entidad Federativa, except to the cities because they have their own price index.

[8] We do not have separated data for LPG and natural gas up to 2011, so from 2006 to 2010 we use the aggregate of two expenditures.

[9] We have a problem to calculate or impute prices for other energy sources (petrol and diesel for housing, carbon, wood, natural gas and other fuels). We have tried several alternatives as impute averages (and minimum) prices of energy sources, weighted by expenditure shares of consumed goods by the household. We do have however an imputation problem with the final number of observations remaining. Since only 32,588 out of 251,437 observations provide positive expenditure on other non-durable goods, a second alternative is to impute average (or minimum) prices of other sources both by groups of expenditure and location. Real prices are again computed using regional RPI. The price of other non-durable goods is calculated as a weighted average of prices of all other non-durable goods outside this group, being the weights the household expenditure. Another alternative we try is to impute this price with the existing price of one (or several) of the components of the non-durables.

Figure 1. Prices evolution (second half of July 2018 = 100)



Notes:
This graph shows the evolution of prices at the national level, although, as indicated above, we use city-level prices in our analysis. The electricity price profile is due to the existence of electricity subsidies in places that face high temperatures during the summer (minimum average temperature above 25ºC, see CFE, 2022).
Source: INEGI (2022c)

2.2. Demand system

We have proceeded in several steps to estimate the demand system. All systems we estimate allow for quadratic effects (i.e., demand systems of rank three) to allow for flexible income responses. So, we base our theoretical model on the Almost Ideal Demand System (AIDS) of Deaton and Muellbauer (1980) and the Quadratic Almost Ideal Demand System (QUAIDS) of Banks et al. (1997)[10]. The QUAIDS assumes the following cost function:

$$ln\ c(u,p) = ln\ a(p) + \frac{ln\ u\ b(p)}{1-\lambda(p) ln\ u} \qquad [1]$$

where *u* is utility, *p* is a set of prices, *a(p)* is a function that is homogenous of degree one in prices, *b(p)* and *λ(p)* are functions that are homogenous of degree zero in prices. Accordingly, the indirect

[10] Details about these two demand models are provided in Deaton and Muellbauer (1980) and Banks et al. (1997) and we omit the details in this paper. It is possible to compare AIDS and QUAIDS elasticities with alternative more flexible results obtained using Exact Affine Stone Index (EASI) demand system proposed by Lewbel and Pendakur (2009). However, this is out of the scope of this paper.

utility function is:

$$\ln V = \left\{ \left[\frac{\ln m - \ln a(p)}{b(p)} \right]^{-1} + \lambda(p) \right\}^{-1} \quad [2]$$

where *m* is total expenditure, *ln a(p)* and *b(p)* are the translog and Cobb-Douglas functions of prices defined as:

$$\ln a(p) = \alpha_0 + \sum_{i=1}^{n} \alpha_i \ln p_i + \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \gamma_{ij} \ln p_i \ln p_j \qquad b(p) = \prod_{i=1}^{n} p_i^{\beta_i} \quad [3]$$

where p_i and p_j are price indices of goods *i* and *j*, respectively. $\lambda(p)$ is a differentiable, homogenous function of degree zero in prices, and defined as $\lambda(p) = \sum_{i}^{n} \lambda_i \ln p_i$.

The model we estimate is expressed in expenditure shares for each of the goods within total non-durable expenditures. We can derive these equations by applying Shephard's lemma to the cost function [1] or Roy's identity to the indirect utility function [2]. As usual, the demand should satisfy additivity of budget shares, homogeneity of price responses and Slutsky symmetry. We impose additivity by omitting one equation out of the system during the estimation. Homogeneity in single equations is imposed by expressing prices in relative terms to the excluded good. System-homogeneity and Slutsky symmetry concern the whole demand system and cannot be imposed, but we test for them after estimation.

One additional feature of our system is that we have gasoline in our set of goods, for which we observe a non-negligible proportion of zero expenditures. The literature shows (see for instance Labeaga and López, 1997) that they correspond mainly to non-participants, i.e., individuals (households) who do not own a vehicle. So, we assume that households take owning before demand decisions. We propose to estimate a probit model in the first stage and calculate the Inverse Mills Ratio (IMR) that, in turn, is used to correct the budget share equations of all goods at the second stage (see Labeaga and López, 1997 or Labeaga et al., 2021). Given that, to simulate the proposed reforms, we need not only the estimated parameters for owners but for the whole population, we also estimate the equations for non-owners (i.e., a kind of Roy model as described by Cameron and Trivedi, 2005, for instance), but for the whole system of equations.

3. Results

We faced several problems in the separate estimation of two very similar types of gasoline (premium and regular). Demand for these products is related to vehicle ownership in a complex manner, first of all to the type of vehicle (extensive margin) but also to the distance driven (intensive margin), We therefore propose the estimation of unconditional and conditional demand models in the spirit of Browning and Meghir (1991) but modelling the decision on ownership as explained before. Given data problems the large number of zeros, we test our estimations and found that separating two different gasolines, magna and premium, does not produce adequate results. Hence, we estimate the demand for aggregate gasoline.

Tables B1-B3 in Appendix B show the estimation results. We observe that prices, household income and many household and housing characteristics are key factors explaining the expenditure shares on food and energy goods. Among sociodemographic variables, geographic location and vehicle ownership appear as relevant demand determinants.

We find, all other variables constant, that the expenditure shares on electricity, are higher in Northern Mexico than in the South. They are also higher in the center for households without a vehicle, but lower for households with a vehicle.

In the case of food, the expenditure share is lower in the north, and in the center but only for households without a vehicle, compared to the south. In turn, the share of LPG expenditure is higher in the north and in the center, while the share of gasoline expenditure is higher in the north and lower in the center, also compared to the south. On the other hand, the significance of income in quadratic terms in all models for all products shows that income effects are not linear.

With respect to price elasticities (see Table 2), the results show that both food and energy products are inelastic goods, with price elasticities being higher, in absolute value, for households without vehicle. Our guess is that the reason behind these results is that owners are richer than non-owners, so that, they are in a better position to face any price shocks. Those who are poor are more motivated – or obliged to adapt to changing prices and their price elasticities therefore higher, while those with more money can afford to pay less attention to price changes. We compare price elasticities across different papers in the literature and we find that our price elasticity of food is similar to that obtained by Ramírez et al. (2021) and it lies within the range of elasticities estimated by Attanasio et al. (2013) for different types of food in Mexico, while the price elasticity of gasoline is also similar to that obtained by Ramírez et al. (2021). The price elasticity of electricity is similar to that estimated by Rosas-Flores et al. (2017), Ortega and Medlock (2021) or Ramírez et al. (2021), while the price elasticity of LPG is in the range of the elasticities estimated by Rosas-Flores et al. (2017) and Labeaga et al. (2021).

For total expenditure elasticities (Table 2), the estimation results show that gasoline and electricity are luxury goods, while food and LPG are normal goods. This suggests that higher energy taxes would fall mainly on the rich. In the case of gasoline, Renner et al. (2018), Ortega and Medlock (2021), Labeaga et al. (2021) or Ramírez et al. (2021) also identify it as a luxury good, while for food the results are similar to those obtained by Renner et al. (2018). In the case of LPG, Rosas-Flores et al. (2017) also identify it as a normal good, while for electricity the results are like those obtained by Labeaga et al. (2021) for households without a vehicle.

If we compare the results of the non-conditional model with the results for households with and without a car, we see that, as indicated above, the price elasticities are higher for households without a vehicle than for households with a vehicle, with the price elasticities of the non-conditional model lying between these values. With respect to income elasticities, they are higher for households without a vehicle than for households with a vehicle (except in the case of food, which are similar). This result may be due to households without a vehicle are generally poorer than households with a vehicle, so their energy consumption is more likely to be below their desired consumption and also because richer households have more substitution possibilities. In this context, given an increase in income, their energy consumption can be expected to increase more (due to the acquisition of energy-consuming durables that were previously unavailable to them) than that of households with a car, which are more likely to already have such durables and are consuming the energy they desire[11].

Table 2. Marshallian own-price and expenditure elasticities

	Food	Gasoline	LPG	Electricity	Other non-durables
Unconditional demand system					
Own-price	-0.907***	-0.481***	-0.476***	-0.672***	-1.804***
Expenditure	0.622***	1.774***	0.889***	0.271***	1.702***
Conditional on owning a vehicle					
Own-price	-0.840***	-0.557***	-0.408***	-0.671***	-1.498***
Expenditure	0.600***	1.337***	0.818***	1.133***	1.481***
Conditional on not owning a vehicle					
Own-price	-0.950***	-	-0.663***	-0.713***	-2.220***
Expenditure	0.590***	-	0.963***	1.172***	1.883***

Note: *** indicates significance at 1 percent.
Source: Own calculations

4. Simulation

4.1. Procedure

Our simulation procedure is as follows: First, we calculate the new shares in 2018 using the parameters obtained from the estimation of the conditional model and the new prices. With the new expenditure shares, if we assume total expenditure on durable goods remains unchanged, we obtain the new expenditures on the different goods considered. Dividing the expenditure shares on the different energy products before and after the reform by their average price in 2018 we obtain the consumption before and after the reform, which allows us to evaluate their impact on energy consumption and associated emissions (using the emission factors), as well as the additional revenue generated by the reform.

We would also be interested in providing some welfare measure arising from the reforms. Despite the various conceptual drawbacks fully described in Banks et al. (1996), the change in household welfare is quantified through the equivalent gain, a money-metric impact of price changes and/or

[11] In this sense, Ortega and Medlock (2021) estimate the demand for various energy products in Mexico by household income level, obtaining higher income elasticities for poorer households.

income changes. An equivalent gain (loss) is the amount of money that needs to be subtracted from (given to) the household to attain the pre-reform level of utility at final prices. We follow the method of King (1983) in computing this measure, although adapting it to the QAIDS, in a similar way to Thomas (2022). In this sense, we evaluate the equivalent loss (gain) for the case of a price change as:

$$EL^h = c(u_0, \boldsymbol{p^0}) - c(u_0, \boldsymbol{p^1}) \qquad [4]$$

where u_0 is pre-reform utility, p^0 and p^1 are the vector of pre- and post-reform prices, respectively, $c(u_0, p^0)$ the observed pre-shock expenditure and $c(u_0, p^1)$ the equivalent income, i.e., the expenditure level at pre-reform prices that is equivalent in utility terms to household expenditure at final prices. We calculate it from the expenditure function [1], using the parameters estimated in the conditional QUAIDS and the prices before and after the reform. The level of utility before the reform is calculated in [2] using the prices before the reform. Finally, to see the net distributional impact of the reforms we consider the index of Reynolds and Smolensky (1977).

4.2. Alternative scenarios

We consider several scenarios for simulation based on the introduction of a carbon tax. We introduce a CO_2 emissions tax on energy products covered by our model, using two alternatives, a tax rate of \$25/tCO_2 and a tax rate of \$50/tCO_2. To calculate the tax rates on each of the energy products we use the emission factors from INECC (2014) for gasoline and LPG, and CRE (2019) for electricity, as well as the OECD exchange rate (2022), to express the tax rates in Mexican pesos. Table 3 summarizes the different alternatives.

Table 3. Alternative scenarios

Energy product	CO_2 tax	
	REFORM 1 25 \$/tCO_2	**REFORM 2 50\$/tCO_2**
Gasoline	1.157 pesos/l	2.314 pesos/l
Electricity	262 pesos/MWh	525 pesos/MWh
LPG	1.495 pesos/kg	2.989 pesos/kg

Source: Own calculations

We consider 2018 prices of magna and premium gasoline from IEA (2019), as well as the price of

LPG from SENER (2019), on which we apply the tax considered to obtain the corresponding price increase because of the reform, assuming full-pass-through to consumers. The results are presented in Table 4. In the case of residential electricity, as noted above, Mexican tariffs are heavily subsidized, so it is unrealistic to assume that the new tax on electricity will be fully passed on to consumers, so we assume that the 25(50) $/tCO_2$ tax will increase the residential price of electricity by 10(20) percent[12].

Since our proposed reforms generate additional tax revenue, we use it to reduce poverty and inequality. To do so, we consider two compensatory schemes: a lump-sum transfer to all households (Transfer 1) and a lump-sum transfer targeted only to the poorest households (defined as those in the bottom three deciles of income, Transfer 2).

Table 4. Price impact of different alternatives (percent of variation)

Energy product	CO_2 tax	
	REFORM 1 25 $/tCO_2$	**REFORM 2 50$/tCO_2$**
Gasoline	5.73	12.13
Electricity	10.00	20.00
LPG	10.49	22.17

Source: Own calculations

4.3. Results of simulation 1

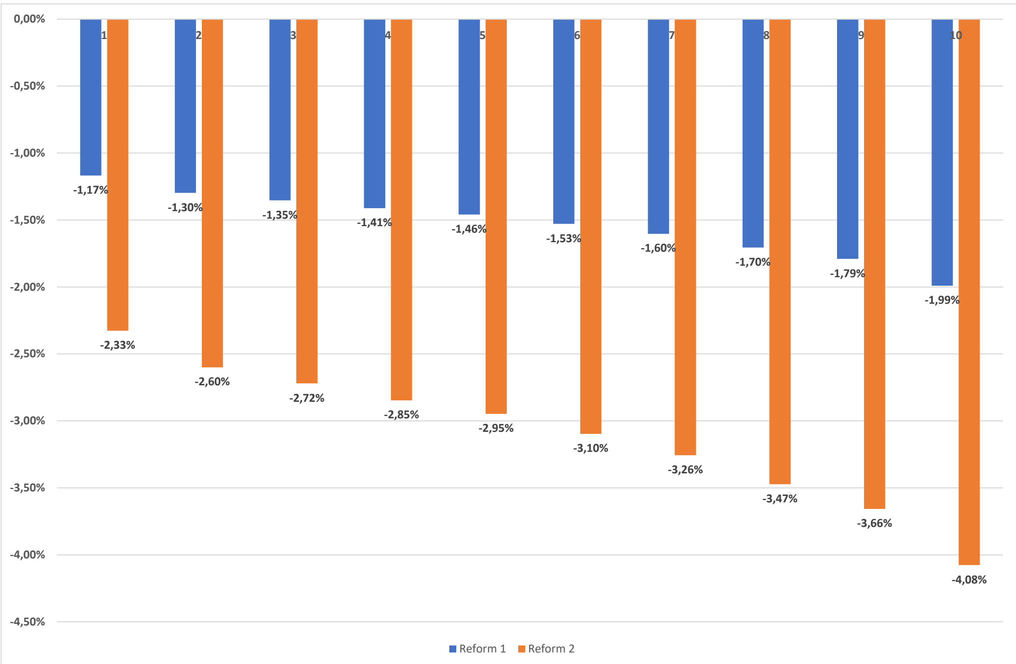
The introduction of a \$25/tCO2 tax on energy products would reduce their demand 5.10 percent, with associated CO_2 emissions reduction of 3.52 percent. The additional revenue obtained would be 27,800 million pesos. In terms of welfare effects, the reform would lead to an average equivalent loss of 1.53 percent, and it has a progressive impact, with the equivalent gain decreasing as the income rises (or equivalent loss increasing with income, Figure 2). This result is because the progressive impact of the increase in the price of gasoline more than offsets the regressive impact derived from the increase in the price of electricity. Thus, if we consider the effect of the reform on each of the energy products separately (Table B4 in Annex B), we see that the increase in the price of electricity has a clearly regressive impact, with the average equivalent gain increasing with

[12] Renner et al. (2018) used data for 2014, and they estimate a 9 percent increase in price of residential electricity with a tax of \$25/tCO_2$.

income, while the increase in the price of gasoline has a progressive effect, since wealthy households are more likely to own a car (see Table A3 in Annex A) and, also to consume more at the intensive margin. On the other hand, the impact of the price of LPG is progressive in the lower income deciles and regressive in the higher income deciles, because average LPG expenditure shares are increasing in the lower income deciles and decreasing in the higher income deciles.

Although the reform affects richer households more, it also harms some poor households, which see their energy costs increase, so the net distributional effect of the reform is unclear. Furthermore, the reform would increase the poverty rate (Figures 3 and 4), except in the south, where it would be very slightly reduced, as well as inequality, both at the national level and in each of the different areas considered (Table 5). So, these results justify the need to introduce compensatory schemes.

Figure 2. Equivalent gain per income decile

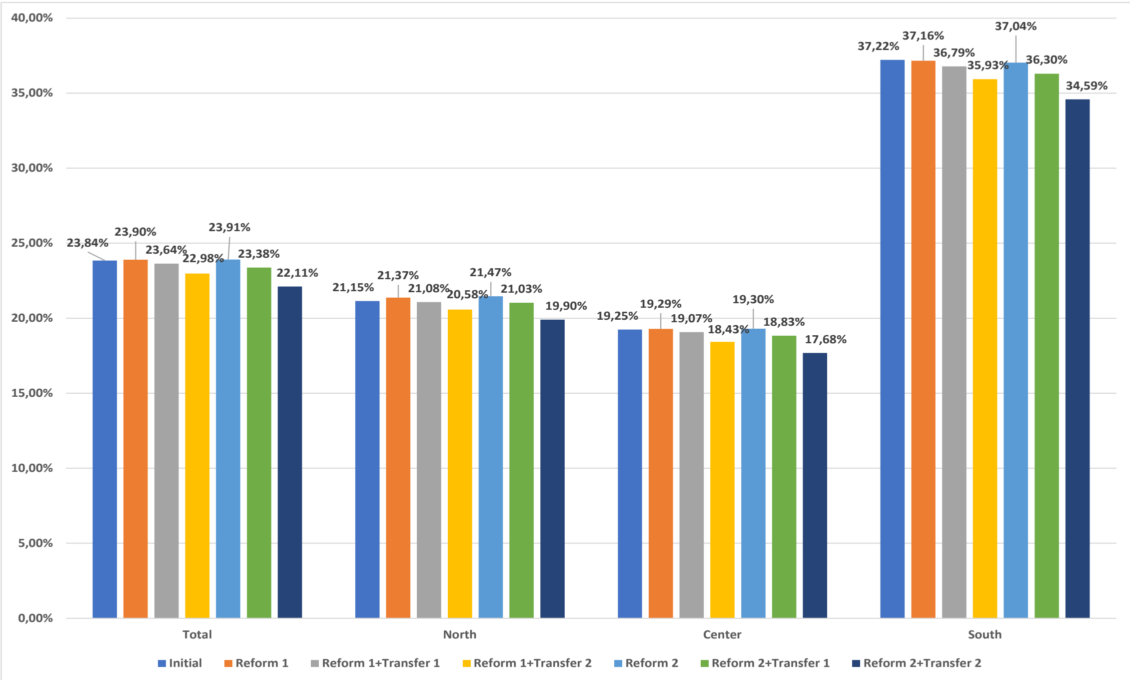


Note. Equivalent gain is defined as the percent of total non-durable expenditure.
Source: Own calculations

If the additional revenue is used to compensate all households through a lump sum transfer, each household would receive an annual amount of 888 pesos. This scheme would reduce inequality and the poverty rate with respect to the situation before the reform, both at the aggregate level and in the different areas considered. However, we can see that average reductions are not very large.

On the other hand, if we introduce the scheme to compensate households in the three bottom deciles of income, each household will receive 2958 pesos per year and the measure would make it possible to achieve greater reductions in inequality and in the poverty rate. In both cases the Reynolds-Smolensky index would become positive (0.0024 and 0.0067, respectively), so that the compensatory package converts a regressive into a net progressive reform, while at the same time reducing inequality and poverty (Figures 3 and 4 for geographical area and urban-rural divide respectively, and Table 5).

Figure 3. Poverty rate by geographical area



Source: Own calculations

Table 5. Gini index

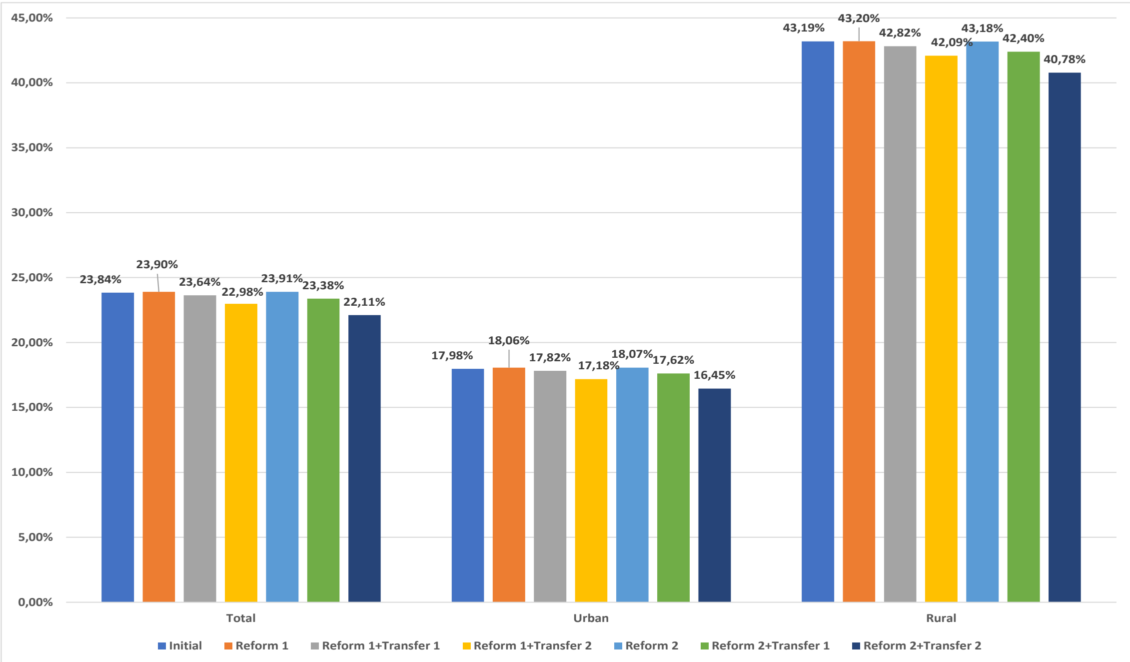
	Total	North	Center	South	Urban	Rural
Initial	0.3711	0.3618	0.3594	0.3881	0.3547	0.3686
Reform 1						
No compensation	0.3716	0.3625	0.3599	0.3884	0.3552	0.3688
Transfer to all households	0.3688	0.3598	0.3573	0.3846	0.3527	0.3646
Transfer to households in the three bottom deciles	0.3644	0.3564	0.3540	0.3767	0.3496	0.3548
Reform 2						
No compensation	0.3721	0.3631	0.3604	0.3886	0.3557	0.3689
Transfer to all households	0.3665	0.3579	0.3554	0.3813	0.3509	0.3608
Transfer to households in the three bottom deciles	0.3582	0.3513	0.3490	0.3662	0.3449	0.3421

Source: Own calculations

4.4. Results of simulation 2

If instead of a carbon tax of \$25/tCO_2, we double the rate to \$50/tCO_2, the demand for the energy products considered would fall by 11.33 percent and the associated CO_2 emissions by 9.74 percent, generating an excess revenue of 54026 million pesos. The welfare impacts (Figure 2) would be as expected of greater magnitude than in the previous simulation, with an average equivalent loss of -3.10 percent, although they would also be progressive, with an equivalent gain decreasing with income, due, once again, to the progressive impact of the increase in the price of gasoline, which offsets the regressive impact of the increase in the price of electricity (see Table B5 in Annex B).

Figure 4. Poverty rate by urban-rural divide



Source: Own calculations

Anyway, this reform would also have a net regressive distributive effect (Reynolds-Smolensky of -0.0009) and would increase the poverty rate (except in the south, where it is slightly reduced, and in rural areas, where it hardly varies), increasing inequality in each of the areas considered to a greater extent than with Reform 1 (Figures 3-4 and Table 5), which justifies the application of a compensatory scheme here as well. In the same scenarios as before for the transfer schemes, now a lump-sum transfer to all households spending all additional revenue represents each household would receive 1725.6 pesos per year, while if the transfer is targeted only to households in the three bottom income deciles, each household would receive 5751.8 pesos per year. Again, with the compensatory schemes (and as before especially the second compensatory package) the reform would contribute to reduce inequality and poverty (Figures 3-4 and Table 5), with a progressive net distributional impact (the Reynolds-Smolensky index with the compensations would be 0.0046 and 0.0129, respectively).

5. Summary and conclusions

This paper analyzes the effects on households of a carbon tax on energy products in Mexico trying to achieve significant reductions in CO_2 emissions associated with domestic energy consumption. First, we estimate a complete demand system for Mexican households, then we use the results to simulate the revenue and distributional effects of the application of a carbon tax with in two scenarios \$25 and \$50/tCO2. Then, we propose to use the additional revenue generated to compensate households for the negative impacts of the reform.

The results show that the reforms considered would reduce energy consumption and associated emissions, and would also have a progressive impact on welfare, affecting richer households more, because of the progressive effect of the gasoline tax, which offsets the regressive impact of the electricity tax. In any case, the reforms, by increasing the energy expenditure of poor households, would increase poverty and inequality in Mexico. The use of the revenue generated through lump-sum transfers, especially if these are targeted to the poorest households, would reduce inequality and poverty relative to the baseline situation without reform, making the reforms with compensatory packages have a net progressive distributional impact.

Therefore, the implementation of a carbon tax on energy goods with properly defined compensation schemes would achieve reductions in energy consumption and associated CO2 emissions of households, contributing to meet the Mexican commitments derived from the Paris agreement, while at the same time reducing inequality and poverty.

References

Akimaya, M., & Dahl, C.A. (2018). Estimating the cross-price elasticity of regular gasoline with respect to the price of premium gasoline. *Journal of Transport Economics and Policy*, *52*(2), 157-180. https://www.jstor.org/stable/90019708

Álvarez, J., & Valencia, F. (2015). Made in Mexico: energy reform and manufacturing growth. *Energy Economics*, *55*, 253–265. https://doi.org/10.1016/j.eneco.2016.01.016

Attanasio, O., Di Mario, V., Lechene, V., & Phillips, D. (2013). Welfare consequences of food prices increases: Evidence from rural Mexico. *Journal of Development Economics*, *104*, 136-151. https://doi.org/10.1016/j.jdeveco.2013.03.009

Banks, J., Blundell, R., & Lewbel, A. (1996). Tax reform and welfare measurement: Do we need demand system estimation? *The Economic Journal*, *106* (438), 1227-1241. https://doi.org/10.2307/2235517

Banks, J., Blundell, R., & Lewbel, A. (1997). Quadratic Engel curves and consumer demand. *Review of Economics and Statistics*, *79*(4), 527-539. https://doi.org/10.1162/003465397557015

Bauer, M., Mar, E., & Elizalde, A. (2003). Transport and energy demand in Mexico: the personal income shock. *Energy Policy*, *31*(14), 1475-1780. https://doi.org/10.1016/S0301-4215(02)00203-3

Berndt, E., & Botero, G. (1985). Energy demand in the transportation sector of Mexico. *Journal of Development Economics*, *17*(3), 219-238. https://doi.org/10.1016/0304-3878(85)90091-4

Berndt, E., & Samaniego, R. (1984). Residential electricity demand in Mexico: a model distinguishing access from consumption. Land Economics, 60, 268-277. https://doi.org/10.2307/3146187

Browning, M., & Meghir, C. (1991). The effects of male and female labor supply on commodity demands. *Econometrica*, *59*(4), 925-951. https://doi.org/10.2307/2938167

Cameron, C., & Trivedi, P. (2005). *Microeconometrics. Methods and Applications*. Cambridge University Press.

Chang, Y., & Martinez-Chambo, E. (2003). Electricity demand analysis using cointegration and error-correction models with time varying parameters: the Mexican case. *Rice University, WP2003-10*.

Comisión Federal de Electricidad (CFE). (2022). *Tarifas*. https://app.cfe.mx/Aplicaciones/CCFE/Tarifas/TarifasCRECasa/Casa.aspx

Comisión Reguladora de Energía (CRE). (2019). *Factor de emisión del sistema eléctrico nacional*. https://www.gob.mx/cms/uploads/attachment/file/442910/Aviso_Factor_de_Emisiones_2018.pdf

Crôtte, A., Noland, R. B., & Graham, D. J. (2010). An analysis of gasoline demand elasticities at the national and local levels in Mexico. *Energy Policy*, *38*(8), 4445-4456. https://doi.org/10.1016/j.enpol.2010.03.076

Deaton, A., & Muellbauer, J. (1980). An almost ideal demand system. *The American Economic*

Review, *70*(3), 312-326. https://www.jstor.org/stable/1805222

Eskeland, G., & Feyzioglu, T. (1997a). Is demand for polluting goods manageable? An econometric study of car ownership and use in Mexico. *Journal of Development Economics*, *53*(2), 423-445. https://doi.org/10.1016/S0304-3878(97)00017-5

Eskeland, G., & Feyzioglu, T. (1997b). Rationing can backfire: the "day without a car" in Mexico City. *The World Bank Economic Review*, *11*(3), 383-408. https://doi.org/10.1093/wber/11.3.383

Foster, J., Greer, J., & Thorbecke, E. (1984). A class of decomposable poverty measures. *Econometrica*, *52*(3), 761–766. https://doi.org/10.2307/1913475

Fullerton, T.M., Ibarra, J., & Elizalde, M. (2015). Microeconomic gasoline consumption anomalies in Mexico: 1997-2007. *Asian Economic and Financial Review*, *5*(4), 709-722. https://doi.org/10.18488/journal.aefr/2015.5.4/102.4.709.722

Gago, A., Labandeira, X., Labeaga, J.M., & López-Otero, X. (2021). Transport taxes and decarbonization in Spain: Distributional impacts and compensation. *Hacienda Pública Española/Review of Public Economics*, *238*(3), 101-136. https://dx.doi.org/10.7866/HPE-RPE.21.3.5

Galindo, L.M. (2005). Short- and long-run demand for energy in Mexico: a cointegration approach. *Energy Policy*, *33*(9), 1179-1185. https://doi.org/10.1016/j.enpol.2003.11.015

Galindo, L.M., & Salinas, E. (1997). La demanda de gasolinas en México, la condición de exogeneidad y el comportamiento de los agentes económicos. In INE-SEMARNAP (Ed.), *Instrumentos económicos y medio ambiente* (pp. 21-45). Dirección General de Regulación Ambiental, Instituto Nacional de Ecología.

Gately, D., & Streifel, S. (1997). Demand for oil products in developing countries. *World Bank Discussion Paper 359*. The World Bank.

Government of Mexico. (2019). *Primer Informe de Gobierno 2018–2019*. Gobierno de México, Presidencia de la República.

Goverment of Mexico. (2020). *Contribución determinada a nivel nacional. Actualización 2020*. Secretaría de Medio Ambiente y Recursos Naturales, Gobierno de México.

Government of Mexico. (2022). *Presupuesto de egresos de la Federación. Ejercicio fiscal 2022*. https://www.pef.hacienda.gob.mx/es/PEF2022/home

Guevara, Z., Sebastian, A., & Dumon, F.C. (2022). Economy-wide impact of conventional development policies in oil-exporting developing countries: The case of Mexico. *Energy Policy*, *161*, 112679. https://doi.org/10.1016/j.enpol.2021.112679

Hancevic, P.I., & Lopez-Aguilar, J. (2019). Energy efficiency programs in the context of increasing block tariffs: The case of residential electricity in Mexico. *Energy Policy*, *131*, 320-331. https://doi.org/10.1016/j.enpol.2019.04.015

Hancevic, P., Núñez, H., & Rosellón, J. (2019). *Tariff schemes and regulations: What changes are needed in the Mexican residential electricity sector to support efficient adoption of green technologies?* Inter-American Development Bank. https://publications.iadb.org/en/tariff-schemes-and-regulations-what-changes-are-needed-mexican-residential-electricity-sector?eloutlink=imf2iadb

Haro, R.A., & Ibarrola, J.L. (2000). Cálculo de la elasticidad precio de la demanda de gasolina en la zona fronteriza norte de México. *Gaceta de Economía*, *6*(11), 237-262.

Heindl, P. (2015). Measuring fuel poverty: general considerations and application to German household data. *FinanzArchiv: Public Finance Analysis*, *71*(2), 178–215. https://www.jstor.org/stable/24807488

Husar, J., & Kitt, F. (2016). *Fossil fuel subsidy reform in Mexico and Indonesia*. OECD-IEA.

INECC. (2014). *Factores de emisión para los diferentes tipos de combustibles fósiles y alternativos que se consumen en México*. Secretaría de Medio Ambiente y Recursos Naturales.

INEGI. (2022a). *Catálogo único de claves de áreas geoestadísticas estatales, municipales y localidades*. https://www.inegi.org.mx/app/ageeml/

INEGI. (2022b). *Encuesta nacional de ingresos y gastos de los hogares (ENIGH)*. https://www.inegi.org.mx/programas/

INEGI (2022c). *Índice nacional de precios al consumidor*. https://www.inegi.org.mx/temas/inpc/

International Energy Agency (IEA). (2019). *Energy prices and taxes for OECD countries. 2019*. IEA.

King, M. A. (1983). Welfare analysis of tax reforms using household data. *Journal of Public Economics*, *21*(2), 183-214. https://doi.org/10.1016/0047-2727(83)90049-X

Labeaga, J.M., Labandeira, X., López-Otero (2021). Energy taxation, subsidy removal and poverty in Mexico. *Environment and Development Economics*, *26*(3), 239-260. https://doi.org/10.1017/S1355770X20000364

Labeaga, J.M. & López, A. (1997). A study of petrol consumption using Spanish panel data. *Applied Economics* 29, 795-802. https://doi.org/10.1080/000368497326714

Lewbel, A., & Pendakur, K. (2009). Tricks with Hicks: The EASI demand system. *American Economic Review*, *99*(3), 827-863. https://doi.org/10.1257/aer.99.3.827

Moshiri, S., & Martinez, M. A. (2018). The welfare effects of energy price changes due to energy market reform in Mexico. *Energy Policy*, *113*, 663-672. https://doi.org/10.1016/j.enpol.2017.11.035

Muñoz, C. (2013). *El impuesto a los combustibles fósiles por contenido de carbono en México*. Secretaría de Hacienda y Crédito Público.

OECD. (2022, February 15). *Exchange rates*. https://data.oecd.org/conversion/exchange-rates.htm

Ortega, A., & Medlock, K. B. (2021). Price elasticity of demand for fuels by income level in Mexican households. *Energy Policy*, *151*, 112132. https://doi.org/10.1016/j.enpol.2021.112132

Ramírez, J. C., Ortiz-Arango, F., & Rosellón, J. (2021). Impact of Mexico's energy reform on consumer welfare. *Utilities Policy*, *70*, 101191. https://doi.org/10.1016/j.jup.2021.101191

Renner, S., Lay, J., & Greve, H. (2018). Household welfare and CO2 emission impacts of energy and carbon taxes in Mexico. *Energy Economics*, *72*, 222-235. https://doi.org/10.1016/j.eneco.2018.04.009

Reyes, O., Escalante, R., & Matas, A. (2010). La demanda de gasolinas en México: efectos y alternativas ante el cambio climático. *Economía: Teoría y Práctica*, *32*, 83-111.

Reynolds, M., & Smolensky, E. (1977). *Public expenditure, taxes and the distribution income: The United States, 1950, 1961, 1970*. Academic Press.

Rodriguez-Oreggia, E., & Yepez-Garcia, R.A. (2014). Income and energy consumption in Mexican households. *World Bank Policy Research Working Paper 6864*. The World Bank.

Rosas-Flores, J. A., Bakhat, M., Rosas-Flores, D., & Zayas, J. L. F. (2017). Distributional effects of subsidy removal and implementation of carbon taxes in Mexican households. *Energy economics*, *61*, 21-28. https://doi.org/10.1016/j.eneco.2016.10.021

Salgado, H., & Bernal, L.E. (2007). Translog cost functions: an application for Mexican manufacturing. *Banco de México, Working Paper nº 2007-08*.

Secretaría de Energía (SENER). (2015). *Prospectiva del sector eléctrico 2015–2029*. http://www.gob.mx/cms/uploads/attachment/file/44328/Prospectiva_del_Sector_Electrico.pdf

Secretaría de Energía (SENER). (2019). *Balance nacional de energía 2018*. Secretaría de Energía.

Secretaría de Gobernación (SEGOB) (2022, April 22). *Acuerdo por el que se dan a conocer los porcentajes, los montos del estímulo fiscal y las cuotas disminuidas del impuesto especial sobre producción y servicios*.
http://www.dof.gob.mx/nota_detalle.php?codigo=5649873&fecha=22/04/2022

Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT). (2021). *Programa de prueba del sistema de comercio de emisiones*. https://www.gob.mx/semarnat/acciones-y-programas/programa-de-prueba-del-sistema-de-comercio-de-emisiones-179414

Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT). (2022). *Inventario nacional de emisiones de gases y compuestos de efecto invernadero (inegycei)*.
https://cambioclimatico.gob.mx/inventario-nacional-de-emisiones-de-gases-y-compuestos-de-efecto-invernadero-2/

Sheinbaum, C., Martínez, M., & Rodríguez, L. (1996). Trends and prospects in Mexican residential energy use. *Energy*, *21*(6), 493-504. https://doi.org/10.1016/0360-5442(96)00011-4

Solís, J.C., & Sheinbaum, C. (2013). Energy consumption and greenhouse gas emission trends in Mexican road transport. *Energy for Sustainable Development*, *17*(3), 280-287. https://doi.org/10.1016/j.esd.2012.12.001

Sterner, T. (1985). Structural change and technology choice: Energy use in Mexican manufacturing industry, 1970–1981. *Energy Economics*, *7*(2), 77-86. https://doi.org/10.1016/0140-9883(85)90022-2

Sterner, T., 1989. Factor demand and substitution in a developing country: energy use in Mexican manufacturing. *Scandinavian Journal of Economics*, *91*(4), 723-739. https://doi.org/10.2307/3440216

Thomas, A. (2022). Who would win from a multi-rate GST in New Zealand: evidence from a QUAIDS model. *New Zealand Economic Papers*, 1-28. https://doi.org/10.1080/00779954.2021.2020324

United Nations (UN). (2015). Paris agreement. https://unfccc.int/sites/default/files/english_paris_agreement.pdf

Vargas, R. (2015). La reforma energética: a 20 años del TLCAN. *Problemas del Desarrollo*, *46*(180), 103–127.

Annex A. Data description

Table A1. Descriptive statistics of main variables

	Observations	Mean	Standard deviation	Minimum	Maximum
Food share	230295	0.5344	0.1788	0.0020	1
Magna gasoline share	230295	0.0775	0.1234	0	0.9894
Premium gasoline share	230295	0.0076	0.0459	0	0.8229
LPG share	230295	0.0410	0.0567	0	0.7865
Electricity share	230295	0.0507	0.0599	0	0.9301
Other non-durable goods share	230295	0.2888	0.1364	0	0.9955
Gasoline share	230295	0.0851	0.1278	0	0.9894
Food price	230295	0.8337	0.1673	0.4792	1.0468
Magna gasoline price	230295	0.7294	0.2306	0.3474	1.0793
Premium gasoline price	230295	0.7213	0.2492	0.3386	1.0865
LPG price	230295	0.7439	0.2092	0.3949	1.0968
Electricity price	230295	1.0584	0.3357	0.5533	2.9848
Other non-durable goods price	230295	0.8577	0.1420	0.4288	1.1123
Gasoline price	230295	0.7265	0.2367	0.3397	1.0865
Total expenditure on non-durables	230295	12429.10	7454.99	1497.42	44821.69
Income	230295	36954.51	28754.24	4065.05	182587.4
Gender	230295	0.2593	0.4382	0	1
Age	230295	48.7931	15.6677	12	110
Members ≥12 years	230295	2.9560	1.4244	1	33
Members <12 years	230295	0.8615	1.0809	0	13
Urban	230295	0.6784	0.4671	0	1
Rural	230295	0.3216	0.4671	0	1
North	230295	0.3175	0.4655	0	1
Center	230295	0.4399	0.4964	0	1
South	230295	0.2426	0.4287	0	1
Less than primary education	230295	0.2660	0.4419	0	1
Primary education	230295	0.2307	0.4213	0	1
Secondary education	230295	0.4013	0.4902	0	1
Higher education	230295	0.1021	0.3027	0	1
Number of rooms	230295	3.7005	1.5414	0	23
Rented housing	230295	0.1268	0.3327	0	1
Owned house with mortgage	230295	0.0834	0.2765	0	1
Owned house without mortgage	230295	0.6332	0.4819	0	1
Dwelling in other situation	230295	0.1567	0.3635	0	1
Van	230295	0.1160	0.3202	0	1
Car	230295	0.2703	0.4441	0	1
Radio recorder	230295	0.2002	0.4002	0	1
Radio	230295	0.2039	0.4029	0	1
TV	230295	0.9295	0.2560	0	1
Videotape player	230295	0.0855	0.2796	0	1
Blender	230295	0.8548	0.3523	0	1
Microwave	230295	0.4189	0.4934	0	1
Refrigerator	230295	0.8576	0.3494	0	1
Stove	230295	0.8905	0.3122	0	1
Washing machine	230295	0.6589	0.4741	0	1
Iron	230295	0.7803	0.4141	0	1
Fan	230295	0.5495	0.4975	0	1
Vacuum cleaner	230295	0.0640	0.2447	0	1
Computer	230295	0.2372	0.4254	0	1
Vehicle	230295	0.4793	0.4996	0	1

Definition of variables:

- Geographical area:
  - North (Baja California, Baja California Sur, Coahuila de Zaragoza, Chihuahua, Durango, Nuevo León, Sinaloa, Sonora, Tamaulipas, Zacatecas)
  - Centre (Aguascalientes, Colima, DF, Guanajuato, Hidalgo, Jalisco, México, Michoacán, Morelos, Nayarit, Puebla, Querétaro, San Luis Potosí, Tlaxcala)
  - South (Campeche, Chiapas, Guerrero, Oaxaca, Quintana Roo, Tabasco, Veracruz de Ignacio de la Llave, Yucatán)
- Area of residence:
  - urban (municipality ≥ 2500 inhabitants)
  - rural (municipality < 2500 inhabitants)
- Quarterly household income
- Gender of household head: female (gender=1), male (gender=0)
- Age of household head
- Level of education of household head: Less than primary education, primary education, secondary education, higher education
- Number of household members ≥12 years
- Number of household members <12 years
- Number of rooms in the dwelling
- Housing tenure: rented, owned with mortgage, owned without mortgage, other situation
- Ownership of car, van, radio recorder, radio, television, videotape player, blender, microwave, refrigerator, stove, washing machine, iron, fan, vacuum cleaner, computer, vehicle (car, van, pickup and/or motorbike).

Comparison of samples by type of gasoline demand

Table A2. Differences in samples by type of gasoline consumption

	Magna gasoline consumers	Premium gasoline consumers
Real income	56541.17	79502.37
Real expenditure on non-durables	18763.66	22231.6
Gender (female=1)	0.1796	0.2102
Age of head of household	47.9586	48.1070
Members ≥12 years	3.1277	2.8565
Members <12 years	0.8573	0.7044
Urban	0.7028	0.8141
North	0.4161	0.3672
Center	0.4113	0.4189
South	0.1725	0.2140
Below primary school	0.1746	0.1075
Primary education	0.2021	0.1400
Secondary education	0.4555	0.4160
Higher education	0.1678	0.3365

Source: Own calculations

Households that consume premium gasoline have on average higher incomes and expenditures on non-durables, a lower number of members (both older and younger), a higher percentage of female-headed households, of households living in urban areas, of households living in the south (and a lower percentage of households living in the north) and of households in which the head has higher education (and a lower percentage of households with less than primary, elementary or secondary education). More than half of the households that consume premium gasoline belong to the two highest income and expenditure deciles.

Comparison of samples by ownership of vehicles

Table A3. Differences in samples by vehicle ownership

	With vehicle	Without vehicle
Real income	56662.24	30840.98
Real expenditure on non-durables	18321.7	10911.75
Gender (female=1)	0.1845	0.3281
Age of head of household	48.2813	49.2641
Members ≥12 years	3.1093	2.8150
Members <12 years	0.8404	0.8810
Urban	0.7063	0.6528
North	0.4041	0.2378
Center	0.4213	0.4570
South	0.1747	0.3052
Below primary school	0.1797	0.3454
Primary education	0.2032	0.2559
Secondary education	0.4468	0.3594
Higher education	0.1703	0.0393

Source: Own calculations

Households with vehicles have higher average incomes and expenditures on non-durables, a higher number of older members (but fewer younger members), a higher percentage of male-headed households, of households living in urban areas, of households living in the north (and a lower percentage of households living in the south), and of households in which the head has higher or secondary education (and a lower percentage of households with less than primary or elementary education).

More than half of the households without a vehicle belong to the first four deciles of income or expenditure on non-durables, while households with a vehicle belonging to the first four deciles account for just over 20% of these households. Therefore, we can assume that households without vehicles, mostly poor households, have higher price elasticities because their consumption is so tight that they must reduce their consumption in the face of any price increase. On the other hand, their income elasticity is lower because they cannot do anything about a marginal increase in their income and would need a significant increase in income to be able to change their consumption.

Annex B. Estimation and simulation results

Table B1. Unconditional QUAIDS estimates

	Food	Gasoline	LPG	Electricity	Other non-durables
Log price food	-0.1088***	-0.0106*	0.0016	-0.0476***	0.1655***
Log price gasoline	-0.0106**	0.0427***	-0.0139***	-0.0185***	0.0003
Log price LPG	0.0016	-0.0139***	0.0224***	0.0029**	-0.0130***
Log price electricity	-0.0476***	-0.0185***	0.0029***	0.0134***	0.0499***
Log price other non-durables	0.1655***	0.0003	-0.0130***	0.0499***	-0.2027***
Log expenditure	-0.1672***	0.0853***	0.0123***	-0.0657***	0.1354***
Log expenditure^2	-0.0125***	-0.0061***	-0.0058***	0.0066***	0.0179***
IV total expenditure	0.2471***	-0.0546***	-0.0063***	0.0226***	-0.2089***
Gender	-0.0078***	-0.0129***	0.0024***	0.0028***	0.0156***
Age	0.0029***	0.0001*	0.0001***	0.0004***	-0.0036***
Age^2	-0.0000***	-0.0000***	0.0000***	-0.0000***	0.0000***
Members ≥ 12 years	0.0327***	-0.0113***	-0.0007***	0.0020***	-0.0227***
Member < 12 years	0.0252***	-0.0088***	-0.0013***	0.0022***	-0.0173***
Urban	0.0215***	-0.0213***	0.0007**	0.0110***	-0.0118***
North	-0.0906***	0.0253***	0.0085***	0.0261***	0.0308***
Center	-0.0078***	-0.0045***	0.0119***	-0.0017***	0.0021**
Less than primary education	-0.0052***	-0.0150***	0.0003	0.0004	0.0194***
Primary education	0.0026	-0.0203***	0.0013***	0.0009*	0.0155***
Secondary education	0.0116***	-0.0212***	0.0005	-0.0006	0.0096***
Number of rooms	-0.0005	0.0009***	0.0009***	0.0013***	-0.0026***
Rented house	-0.0075***	0.0023***	-0.0018***	-0.0026***	0.0095***
Owned house with mortgage	-0.0066***	0.0077***	-0.0062***	-0.0012**	0.0064***
Owner house without mortgage	0.0048***	0.0026***	-0.0010***	0.0017***	-0.0082***
Van	-0.0260***	0.0903***	-0.0035***	0.0016***	-0.0625***
Car	-0.0303***	0.1084***	-0.0058***	-0.0002	-0.0721***
Radio recorder	0.0032***	-0.0052***	0.0008***	0.0008***	0.0004
Radio	-0.0006	-0.0022***	0.0010***	0.0010***	0.0007
TV	0.0124***	0.0039***	0.0016***	0.0057***	-0.0158***
Videotape player	0.0074***	-0.0097***	0.0016***	0.0039***	-0.0032**
Blender	0.0241***	-0.0035***	0.0050***	0.0007*	-0.0263***
Microwave	-0.0010	0.0044***	-0.0008***	0.0025***	-0.0051***
Refrigerator	0.0023	-0.0008	0.0015***	0.0080***	-0.0110***
Stove	0.0097***	-0.0090***	0.0340***	0.0065***	-0.0412***
Washing machine	0.0098***	0.0011**	0.0005*	0.0012***	-0.0125***
Iron	0.0152***	-0.0026***	0.0018***	0.0013***	-0.0157***
Fan	-0.0023**	-0.0013***	-0.0103***	0.0098***	0.0041***
Vacuum cleaner	0.0095***	-0.0004	-0.0009*	0.0039***	-0.0121***
Computer	0.0163***	0.0042***	-0.0011***	0.0004	-0.0197***
Constant	0.5774***	0.0283***	-0.0131***	0.0657***	0.3417***

Note: ***, **, * report significance at 1%, 5% and 10%, respectively.
Source: Own calculations

Table B2. Conditional QUAIDS estimates (owners)

	Food	Gasoline	LPG	Electricity	Other non-durables
Log price food	-0.0563***	-0.0303***	0.0068*	-0.0247***	0.1044***
Log price gasoline	-0.0303***	0.0778***	-0.0183***	-0.0225***	-0.0068
Log price LPG	0.0068	-0.0183***	0.0232***	0.0007	-0.0125***
Log price electricity	-0.0247***	-0.0225***	0.0007	0.0181***	0.0284***
Log price other non-durables	0.1044***	-0.0068	-0.0125***	0.0284***	-0.1136***
Log expenditure	-0.1295***	0.0951***	0.0099***	-0.0243***	0.0487***
Log expenditure^2	-0.0160***	-0.0101***	-0.0049***	0.0090***	0.0220***
IV total expenditure	0.2264***	-0.0602***	-0.0049***	-0.0265***	-0.1349***
Gender	-0.0181***	0.0122***	-0.0000	-0.0105***	0.0164***
Age	0.0035***	-0.0012***	0.0003***	0.0008***	-0.0034***
Age^2	-0.0000***	0.0000***	0.0000	-0.0000***	0.0000***
Members ≥ 12 years	0.0303***	-0.0149***	0.0000	-0.0021***	-0.0133***
Member < 12 years	0.0246***	-0.0149***	-0.0004**	-0.0006***	-0.0087***
Urban	0.0166***	0.0005	-0.0028***	-0.0027***	-0.0116***
North	-0.0776***	0.0234***	0.0071***	0.0377***	0.0093***
Center	-0.0009	-0.0042***	0.0098***	-0.0030***	-0.0016
Less than primary education	-0.0098***	-0.0095***	0.0003	-0.0077***	0.0268***
Primary education	-0.0011	-0.0157***	0.0017***	-0.0054***	0.0205***
Secondary education	0.0081***	-0.0158***	-0.0001	-0.0045***	0.0122***
Number of rooms	0.0021***	-0.0030***	0.0013***	0.0033***	-0.0038***
Rented house	-0.0099***	0.0137***	-0.0016***	-0.0038***	0.0016
Owned house with mortgage	-0.0056**	0.0084***	-0.0050***	0.0022***	0.0001
Owner house without mortgage	0.0077***	-0.0104***	-0.0001	0.0086***	-0.0058***
Radio recorder	0.0058***	-0.0037***	0.0007*	-0.0024***	-0.0003
Radio	0.0019	-0.0035***	0.0017***	0.0003	-0.0003
TV	0.0173***	-0.0193***	-0.0011	0.0078***	-0.0047*
Videotape player	0.0056***	-0.0070***	0.0017***	0.0011*	-0.0013
Blender	0.0254***	-0.0136***	0.0043***	0.0019***	-0.0180***
Microwave	-0.0002	-0.0018*	0.0001	0.0077***	-0.0057***
Refrigerator	0.0089***	-0.0219***	0.0012	0.0162***	-0.0044**
Stove	0.0194***	-0.0239***	0.0257***	0.0109***	-0.0321***
Washing machine	0.0196***	-0.0207***	0.0013***	0.0101***	-0.0103***
Iron	0.0170***	-0.0072***	0.0017***	0.0002	-0.0118***
Fan	0.0034***	-0.0105***	-0.0091***	0.0122***	0.0040***
Vacuum cleaner	0.0096***	-0.0083***	-0.0008	0.0072***	-0.0077***
Computer	0.0168***	-0.0023**	-0.0011***	0.0054***	-0.0188***
Heckman’s lambda	0.0333***	-0.0771***	0.0011	0.0559***	-0.0132***
Constant	0.4110***	0.3222***	-0.0135***	-0.0699***	0.3502***

Note: ***, **, * report significance at 1%, 5% and 10%, respectively.
Source: Own calculations

Table B3. Conditional QUAIDS estimates (non-owners)

	Food	GLP	Electricity	Other non-durables
Log price food	-0.3142***	-0.0298***	-0.0595***	0.4034***
Log price LPG	-0.0298***	-0.0142***	0.0063***	0.0377***
Log price electricity	-0.0595***	0.0063***	0.0212***	0.0320***
Log price other non-durables	0.4034***	0.0377***	0.0320***	-0.4731***
Log expenditure	0.0186	0.0987***	-0.0137***	-0.1035***
Log expenditure^2	-0.0214***	-0.0080***	0.0021***	0.0273***
IV total expenditure	0.3135***	-0.0077***	-0.0392***	-0.2666***
Gender	0.0103***	0.0037***	-0.0212***	0.0073**
Age	0.0020***	0.0000	0.0012***	-0.0032***
Age^2	0.0000***	0.0000***	-0.0000***	0.0000***
Members ≥ 12 years	0.0389***	-0.0014***	-0.0038***	-0.0338***
Member < 12 years	0.0281***	-0.0018***	-0.0017***	-0.0246***
Urban	0.0292***	0.0030***	-0.0071***	-0.0251***
North	-0.1171***	0.0081***	0.0509***	0.0582***
Center	-0.0185***	0.0120***	0.0092***	-0.0026
Less than primary education	0.0177***	0.0023*	-0.0112***	-0.0087**
Primary education	0.0225***	0.0026**	-0.0100***	-0.0151***
Secondary education	0.0288***	0.0021**	-0.0085***	-0.0225***
Number of rooms	-0.0050***	0.0004**	0.0053***	-0.0008
Rented house	-0.0044**	-0.0021***	-0.0069***	0.0134***
Owned house with mortgage	-0.0107***	-0.0072***	0.0046***	0.0134***
Owner house without mortgage	-0.0008	-0.0011*	0.0093***	-0.0073***
Radio recorder	0.0015	0.0012**	-0.0032***	0.0005
Radio	-0.0038**	0.0006	0.0008**	0.0024*
TV	0.0097***	0.0019***	0.0085***	-0.0201***
Videotape player	0.0106***	0.0018**	-0.0021***	-0.0103***
Blender	0.0229***	0.0049***	0.0018***	-0.0295***
Microwave	-0.0040**	-0.0014***	0.0090***	-0.0037**
Refrigerator	-0.0023	0.0010	0.0188***	-0.0175***
Stove	0.0103***	0.0351***	0.0073***	-0.0527***
Washing machine	0.0020	0.0001	0.0117***	-0.0138***
Iron	0.0169***	0.0020***	0.0004	-0.0193***
Fan	-0.0069***	-0.0115***	0.0127***	0.0057***
Vacuum cleaner	-0.0061	-0.0035**	0.0155***	-0.0059
Computer	0.0104***	-0.0012*	0.0073***	-0.0165***
Heckman's lambda	0.0570***	0.0027	-0.0589***	-0.0008
Constant	1.1100***	-0.3036***	-0.0172	0.2108***

Note: ***, **, * report significance at 1%, 5% and 10%, respectively.
Source: Own calculations

Table B4. Equivalent gain (Reform 1). Impact by energy good

	ELECTRICITY		GASOLINE				LPG			
			Whole sample		Households with vehicle		Whole sample		Households with positive spending in LPG	
	Equivalent gain	% losers	Equivalent gain	% losers	Equivalent gain	% losers	Equivalent ga	% losers	Equivalent gain	% losers
Total	-0.57	99.7	-0.50	47.5	-1.09	99.9	-0.46	98.2	-0.50	99.8
Income deciles										
1	-0.72	100	-0.05	10.9	-0.50	97.9	-0.39	90.6	-0.54	99.6
2	-0.67	99.9	-0.14	20.5	-0.71	99.9	-0.48	97.4	-0.57	99.9
3	-0.63	99.9	-0.22	27.4	-0.82	100	-0.50	98.5	-0.57	99.7
4	-0.60	99.7	-0.31	36.3	-0.88	100	-0.50	99.0	-0.54	99.9
5	-0.58	99.8	-0.39	41.7	-0.95	100	-0.49	99.2	-0.53	99.9
6	-0.55	99.7	-0.49	49.1	-1.01	100	-0.49	99.3	-0.52	99.9
7	-0.52	99.6	-0.61	57.7	-1.07	100	-0.47	99.3	-0.50	99.9
8	-0.49	99.2	-0.76	67.5	-1.14	100	-0.46	99.4	-0.47	99.7
9	-0.46	99.7	-0.90	75.8	-1.20	100	-0.43	99.6	-0.45	99.9
10	-0.46	99.6	-1.15	88.0	-1.31	100	-0.39	99.5	-0.40	99.8

Notes:
Equivalent loss is expressed as a percentage of total expenditure on non-durables.
Losers: Equivalent loss<0
For each energy product the equivalent gain is calculated assuming that the reform only affects the price of the energy product considered.
Source: Own calculations

Table B5. Equivalent gain (Reform 2). Impact by energy good

	ELECTRICITY		GASOLINE				LPG			
			Whole sample		Households with vehicle		Whole sample		Households with positive spending in LPG	
	Equivalent gain	% losers	Equivalent gain	% losers	Equivalent gain	% losers	Equivalent ga	% losers	Equivalent gain	% losers
Total	-1.11	99.8	-1.06	47.5	-2.28	99.9	-0.95	98.4	-1.03	99.8
Income deciles										
1	-1.39	100	-0.11	10.9	-1.05	98.4	-0.81	91.1	-1.11	99.6
2	-1.30	99.9	-0.30	20.5	-1.49	99.9	-0.99	97.7	-1.16	99.9
3	-1.23	99.9	-0.46	27.4	-1.72	100	-1.03	98.6	-1.16	99.7
4	-1.17	99.7	-0.66	36.3	-1.86	100	-1.03	99.1	-1.11	99.9
5	-1.12	99.8	-0.82	41.7	-1.99	100	-1.01	99.3	-1.09	99.9
6	-1.07	99.8	-1.03	49.1	-2.12	100	-1.01	99.5	-1.07	99.9
7	-1.02	99.6	-1.28	57.7	-2.24	100	-0.98	99.4	-1.03	99.9
8	-0.96	99.2	-1.60	67.5	-2.38	100	-0.94	99.6	-0.98	99.9
9	-0.91	99.8	-1.89	75.8	-2.51	100	-0.89	99.6	-0.92	99.9
10	-0.91	99.8	-2.40	88.0	-2.74	100	-0.80	99.6	-0.82	99.8

Notes:
Equivalent loss is expressed as a percentage of total expenditure on non-durables.
Losers: Equivalent loss<0
For each energy product the equivalent gain is calculated assuming that the reform only affects the price of the energy product considered.
Source: Own calculations