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Distributional impacts of carbon taxation in Mexico*

Impactos distributivos de la fiscalidad sobre el carbono en México

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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.*

Resumen

El principal objetivo de este artículo es analizar el impacto distributivo de la fiscalidad sobre el carbono en los hogares mexicanos. En primer lugar, estimamos un sistema de demanda de bienes no duraderos de los hogares, prestando una atención especial a los bienes relacionados con la energía. A continuación, utilizamos los resultados para simular la introducción de un impuesto al carbono, analizando su potencial para generar ingresos con la finalidad de llevar a cabo distintas políticas redistributivas, con el objetivo final de reducir la desigualdad y la pobreza. Además, utilizamos los resultados para evaluar los efectos del impuesto sobre la demanda y la reducción de emisiones.

Palabras claves: *emisiones, imposición al carbono, distribución, pobreza, México.*

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1. Introduction

Starting from the Kyoto Protocol in February 2005, and continuing more vigorously in the Paris Agreement (UN, 2015), many signatory countries implemented policies to achieve quantitative reductions in greenhouse gas (GHG) emissions through various instruments, including carbon pricing, either through taxes or emission for emissions allowances. Explicit carbon pricing provides incentives for businesses and households to reduce carbon-intensive energy use and switch to clean fuels, as well as a price signal to mobilise private investments in clean technologies, is more flexible than regulations, provides continuous incentives for mitigation, reduces rebound effects, increases government revenue and generates environmental co-benefits, such as reductions in local pollution (IMF/OECD, 2021). In practice, however, the incentive effects of environmental taxes are often limited for three main reasons: the use of tax rates that are too low to achieve substantial environmental improvement[1], the existence of exemptions or rebates for energy-intensive industries, and the tendency to use taxes on households, where in many cases price elasticity is low and/or product substitution, at least in the short run, is not possible (Fujiwara et al., 2006). So, despite the increasing use of climate policies and legislation, these, overall, have not achieved a substantial reduction in GHG emissions (Somanathan et al., 2014).

Among the environmental taxation actions carried out by many governments, the policies implemented by the European Union countries stand out, whose environmental tax revenues increased by 9.5 % in real terms between 2002-2014 (Speck & Paleari, 2016). Finland was the first country to introduce a carbon tax in the early 1990s and its example was followed by many countries, generally accompanying this measure with other carbon pricing instruments, such as energy taxes, with the aim of reducing energy consumption (Vallés-Giménez & Zárate-Marco, 2020). Thus, there are currently 68 carbon pricing initiatives in 46 national and 36 sub-national jurisdictions, covering 12 Gt of CO_2 equivalent emissions, which represents 23 % of global GHG emissions (World Bank, 2022). Still, about 60 % of carbon emissions from energy use in Organisation for Economic Co-operation and Development (OECD) and G20 countries remained untaxed in 2018, with effective carbon tax rates being particularly low in the power and industrial sectors (OECD, 2021b). Although the rate was reduced to 51 % in 2021, existing levels of taxation are not high enough to achieve a successful transition to net zero emissions (OECD, 2021a), as the average global emissions price is only \$2/tonne (Parry, 2019) and only 3.76 % of global emissions are regulated by a carbon price equal to or above \$40/t CO_2 (World Bank, 2021).

Among the commitments of the Paris Agreement (UN, 2015), the signatory countries agreed to reduce their greenhouse gas emissions, translating this

[1] To limit global warming to 2 °C or less a high level of taxation is required, such as an immediate global carbon tax that rises rapidly to \$75/tCO_2 by 2030 (IMF, 2019).

commitment into Nationally Determined Contributions (NDCs). Mexico committed unconditionally to reduce its GHG emissions by 22 % in 2030 compared to the baseline scenario estimated for 2013 (991MtCO_2e). In addition, conditional commitments would increase emissions mitigation to 36 % in 2030 compared to the baseline scenario (Government of Mexico, 2020)[2]. Within Mexican GHG emissions, energy-related emissions stand out, accounting for 63.5 % of gross GHG emissions and 87.5 % 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 & 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 IEA, 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 a 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 as the overvaluation of national currency and consequent problems of competitiveness 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 % in the tax rate on

[2] 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.

gasoline, although currently (week of 23-29 April 2022) the fiscal stimulus is 100 % (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 % of the total cost of the service (Hancevic et al., 2019), with electricity subsidies amounting to close to 0.3 % of GDP in 2022 (73 billion pesos), see Government of Mexico (2022).

The 2013 energy reform also provided for the introduction of an emissions trading system (ETS). Mexico initiated a 36-month trial ETS programme in 2020, in which only installations operating in the energy and manufacturing 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 % 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 % of Mexican households are in poverty, especially prominent in the south of the country (over 37 % of households in poverty) and in rural areas (almost 43 %). Regarding inequality, the Gini index shows that inequality is also higher in the south and in rural areas.

The academic literature on energy demand in Mexico has mainly focused on studying transport fuel demand (Bernt & Botero, 1985; Gately & Streifel, 1997; Eskeland & Feyzioglu, 1997a, 1997b; Galindo & Salinas, 1997; Haro & Ibarrola, 2000; Bauer et al., 2003; Reyes et al., 2010; Crôtte et al., 2010; Solís & Sheinbaum, 2013; Rodriguez-Oreggia & Yepez-Garcia, 2014; Fullerton et al., 2015; Akimaya & Dahl, 2018). Some papers have analysed electricity demand (Berndt & Samaniego,

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).

1984; Chang & Martinez-Chambo, 2003; Salgado & Bernal, 2007; Hancevic & 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:[3] food at home, low octane gasoline (magna), high octane gasoline (premium), liquefied petroleum gases (LPG), electricity, and other non-durable goods:[4] 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 statistics are in Table A1 in Appendix A.[5] Thus, 31.7% of households live in the north of the country, while 44% live in the center and the remaining 24.3% in the south. Furthermore, 67.8% of households live in urban areas, 63.3% own a house without a mortgage, 12.7% rent the house where they live, 27% own a car, and 48% own a vehicle (car, van, pickup and/or motorbike). The household head is, on average 48.8 years old, 25.9% of household heads are women, and 10.2% report higher education level, while 26.6% 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

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

[4] 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 the household (food, drinks and tobacco), diesel and gas for housing, petrol, diesel for transport, wood, fuel for heating and natural gas.

[5] 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.

level in the cities.[6] INEGI provides price data for 46 cities for the whole sample period,[7] which we assign to Entidades Federativas.[8]

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,[9] 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.[10] Figure 1 shows some graphical evidence on the evolution of prices.

[6] INEGI also provides information for the INPC for Entidades Federativas, which we introduce, although prices at this level are only available from 2018.

[7] 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).

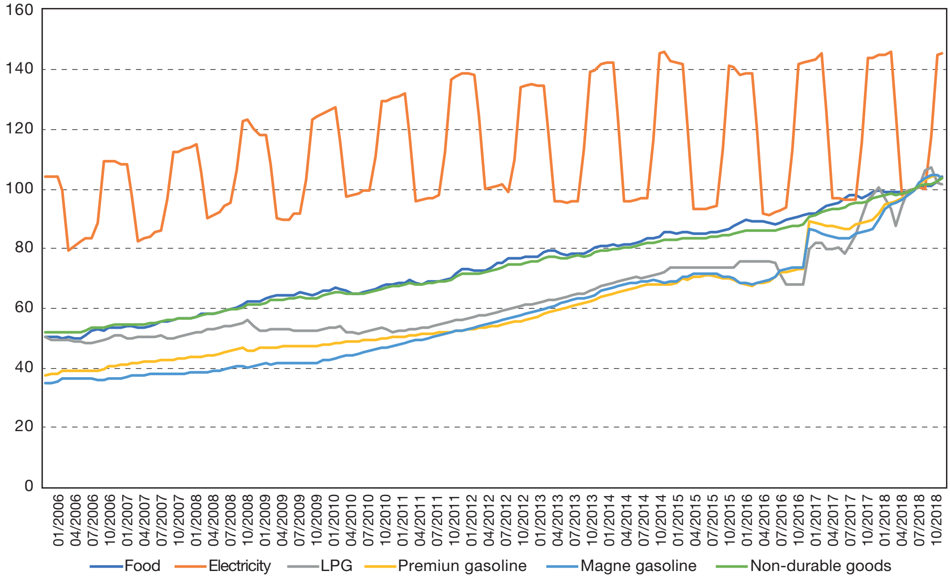
[8] We assign prices to Entidades Federativas as follows: in those Entidades Federativas with only one city, we consider that the prices of the city correspond to the prices of the Entidad Federativa. If there is a Entidad Federativa with several cities, we calculate a population-weighted average of 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.

[9] 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.

[10] 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 25 ºC, see CFE, 2022).

SOURCE: INEGI (2022c).

2.2. Demand system

We have proceeded in several steps to estimate the demand system.[11] 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

[11] Applied general equilibrium models permit analysis of the impacts of policy measures on an economy-wide scale. They are therefore a powerful instrument for analysing efficiency as well as other macroeconomic effects of public policies. Nevertheless, despite their potential, in a non-integrated context with microdata, their capacity of evaluating the distributional effects of such policies on households is limited to the number of different household-types included in the model. Therefore, it lacks the ability to calculate welfare related aspects. By contrast, microeconomic models represent the most usual approach to analysing distributional effects. The most interesting aspect of the use of this data is that it allows the large disparity existing between economic agents to be considered. The main drawback of microsimulation models is that their partial equilibrium setting does not allow relative prices to be endogenized, which leads to potentially biased results. Furthermore, they are not the most appropriate framework for analysing efficiency aspects deriving from public policies. As such, a trade-off must be acknowledged between the analysis of distributional effects and efficiency, and it will be up to researchers to choose from the diversity of instruments available (Labandeira et al., 2007). Since in this paper we are interested in analysing the distributional impacts of the reforms, rather than efficiency issues, we have chosen to link behavioural responses of households to a microsimulation tool.

Ideal Demand System (QUAIDS) of Banks et al. (1997).[12] 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 $\lambda(p)$ are functions that are homogenous of degree zero in prices. Accordingly, the indirect utility function is:

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

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

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

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

[12] 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.

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 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[13].

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 %.
SOURCE: Own calculations.

[13] 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.

4. Simulation step

4.1. Simulation 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 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:

$$EL^h = c(u_0, p^0) - c(u_0, p^1) \quad [4]$$

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)%.[14]

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. Simulation results. Reform 1

The introduction of a $25/t CO_2 tax on energy products would reduce their demand 5.10%, with associated CO_2 emissions reduction of 3.52%. 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%, and it has a progressive impact, with

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

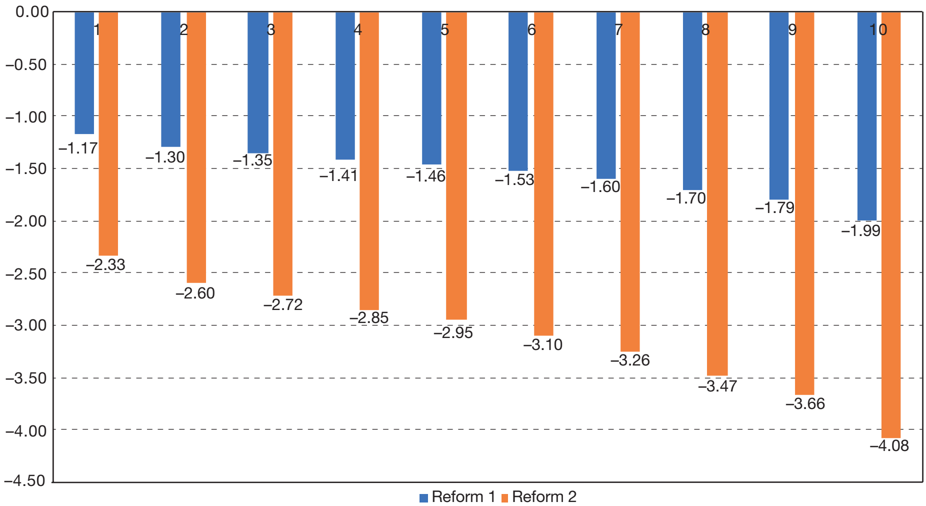
the equivalent gain decreasing as the income rises (or equivalent loss increasing with income, Figure 2). This result is because the progressive impact of the increase in the price of gasoline more than offsets the regressive impact derived from the increase in the price of electricity. Thus, if we consider the effect of the reform on each of the energy products separately (Table B4 in Appendix B), we see that the increase in the price of electricity has a clearly regressive impact, with the average equivalent gain increasing with 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 Appendix 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. Finally, if we analyze the results by household type (Figure 3), we see that, although they are quite similar, the equivalent loss will be, on average, slightly higher for couples without children, and slightly lower for couples with children.

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 4 and 5), 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

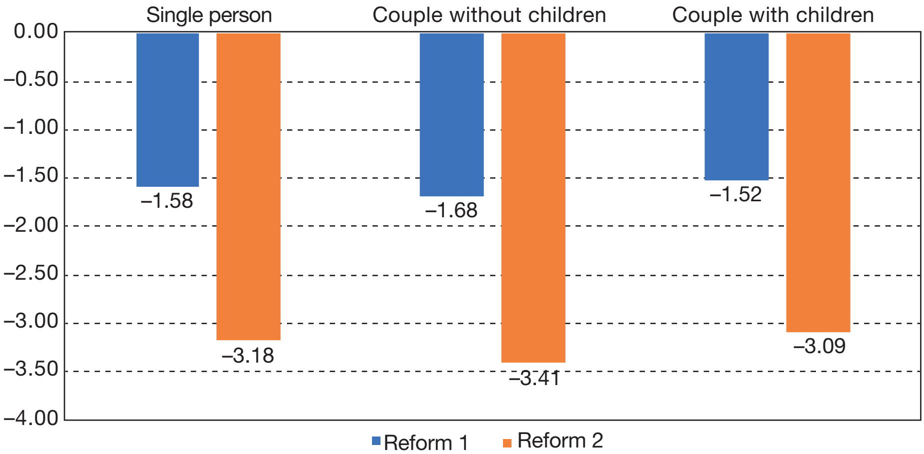
EQUIVALENT GAIN PER INCOME DECILE

(In %)



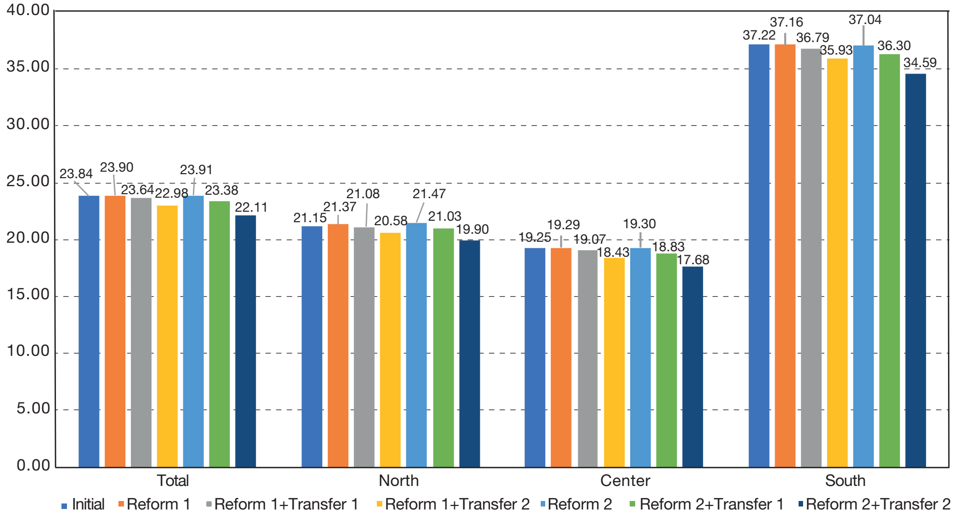
NOTE: Equivalent gain is defined as the percent of total non-durable expenditure.
SOURCE: Own calculations.

FIGURE 3
EQUIVALENT GAIN BY HOUSEHOLD TYPE
(In %)



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

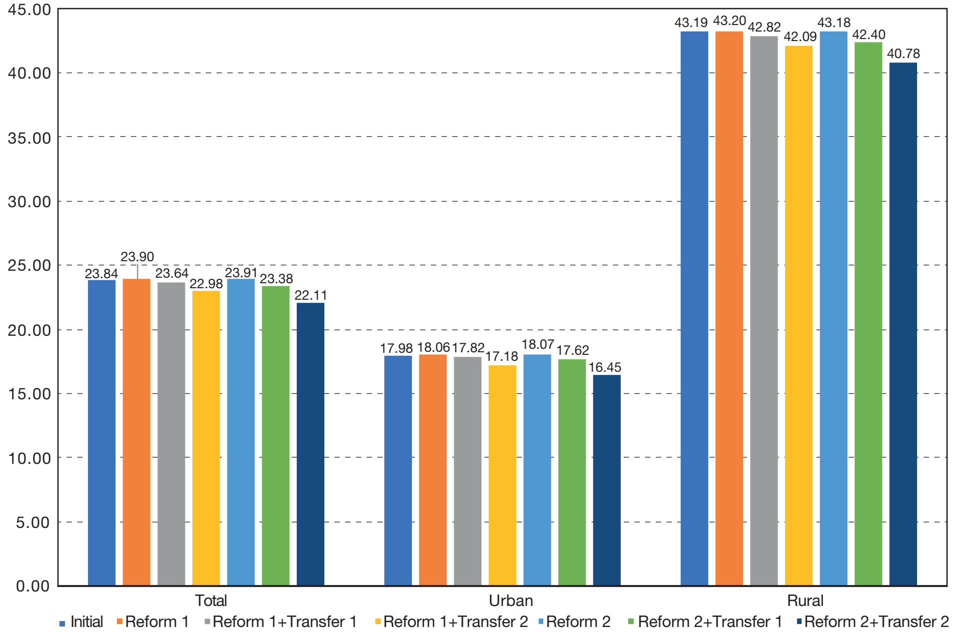
FIGURE 4
POVERTY RATE BY GEOGRAPHICAL AREA
(In %)



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,[15] while at the same time reducing inequality and poverty (Figures 4 and 5 for geographical area and urban-rural divide respectively, and Table 5).

FIGURE 5
POVERTY RATE BY URBAN-RURAL DIVIDE
(In %)



SOURCE: Own calculations.

[15] Gonzalez (2012), using a general equilibrium model to assess the distributional effects of a carbon tax in Mexico, also shows that recycling revenue through transfers to households (in his case through a food subsidy) allows the carbon tax to have a progressive impact. He provides global measures of redistribution at the cost of losing detailed heterogeneity.

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 Simulation results. Reform 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 % and the associated CO_2 emissions by 9.74 %, 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 %, 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 Appendix B). Also, as in Reform 1, the results by household type show an equivalent loss, on average, slightly lower for couples with children and slightly higher for couples without children (Figure 3).

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 4-5 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 4-5 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 within two scenarios, \$25 and \$50/tCO_2. 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 CO_2 emissions of households, contributing to meet the Mexican commitments derived from the Paris agreement, while at the same time reducing inequality and poverty.

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APPENDIX A

DATA DESCRIPTION

TABLE A1
DESCRIPTIVE STATISTICS OF MAIN VARIABLES

	Observations	Mean	Standard deviation	Minimum	Maximum
Food share	230,295	0.5344	0.1788	0.0020	1
Magna gasoline share	230,295	0.0775	0.1234	0	0.9894
Premium gasoline share	230,295	0.0076	0.0459	0	0.8229
LPG share	230,295	0.0410	0.0567	0	0.7865
Electricity share	230,295	0.0507	0.0599	0	0.9301
Other non-durable goods share	230,295	0.2888	0.1364	0	0.9955
Gasoline share	230,295	0.0851	0.1278	0	0.9894
Food price	230,295	0.8337	0.1673	0.4792	1.0468
Magna gasoline price	230,295	0.7294	0.2306	0.3474	1.0793
Premium gasoline price	230,295	0.7213	0.2492	0.3386	1.0865
LPG price	230,295	0.7439	0.2092	0.3949	1.0968
Electricity price	230,295	1.0584	0.3357	0.5533	2.9848
Other non-durable goods price	230,295	0.8577	0.1420	0.4288	1.1123
Gasoline price	230,295	0.7265	0.2367	0.3397	1.0865
Total expenditure on non-durables	230,295	12,429.10	7,454.99	1,497.42	44,821.69
Income	230,295	36,954.51	28,754.24	4,065.05	182,587.4
Gender	230,295	0.2593	0.4382	0	1
Age	230,295	48.7931	15.6677	12	110
Members ≥12 years	230,295	2.9560	1.4244	1	33
Members <12 years	230,295	0.8615	1.0809	0	13
Urban	230,295	0.6784	0.4671	0	1
Rural	230,295	0.3216	0.4671	0	1
North	230,295	0.3175	0.4655	0	1
Center	230,295	0.4399	0.4964	0	1
South	230,295	0.2426	0.4287	0	1
Less than primary education	230,295	0.2660	0.4419	0	1
Primary education	230,295	0.2307	0.4213	0	1
Secondary education	230,295	0.4013	0.4902	0	1
Higher education	230,295	0.1021	0.3027	0	1
Number of rooms	230,295	3.7005	1.5414	0	23
Rented housing	230,295	0.1268	0.3327	0	1

SOURCE: Own calculations.

TABLE A1 *(Cont.)*

DESCRIPTIVE STATISTICS OF MAIN VARIABLES

	Observa-tions	Mean	Standard deviation	Mini-mum	Maxi-mum
Owned house with mortgage	230,295	0.0834	0.2765	0	1
Owned house without mortgage	230,295	0.6332	0.4819	0	1
Dwelling in other situation	230,295	0.1567	0.3635	0	1
Van	230,295	0.1160	0.3202	0	1
Car	230,295	0.2703	0.4441	0	1
Radio recorder	230,295	0.2002	0.4002	0	1
Radio	230,295	0.2039	0.4029	0	1
TV	230,295	0.9295	0.2560	0	1
Videotape player	230,295	0.0855	0.2796	0	1
Blender	230,295	0.8548	0.3523	0	1
Microwave	230,295	0.4189	0.4934	0	1
Refrigerator	230,295	0.8576	0.3494	0	1
Stove	230,295	0.8905	0.3122	0	1
Washing machine	230,295	0.6589	0.4741	0	1
Iron	230,295	0.7803	0.4141	0	1
Fan	230,295	0.5495	0.4975	0	1
Vacuum cleaner	230,295	0.0640	0.2447	0	1
Computer	230,295	0.2372	0.4254	0	1
Vehicle	230,295	0.4793	0.4996	0	1

SOURCE: Own calculations.

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 $\geq$ 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	56,541.17	79,502.37
Real expenditure on non-durables	18,763.66	22,231.6
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	56,662.24	30,840.98
Real expenditure on non-durables	18,321.7	10,911.75
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.

APPENDIX 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 gain	% 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 postive spending in LPG	
	Equivalent gain	% losers	Equivalent gain	% losers	Equivalent gain	% losers	Equivalent gain	% 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.