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Abstract

Equity and efficiency are crucial issues behind any tax reform, but they are particularly relevant in countries with high inequality and large shares of poverty. This paper provides a comprehensive socio-economic empirical assessment of Mexico's recently implemented tax reforms in the energy domain, and of a hypothetical (partial) removal of existing electricity subsidies. Using the rich *National Household Income and Expenditure Survey* within the context of a demand system adjustment of non-durable goods, this article provides the public-revenue, environmental and distributional impacts from the simulation of different combinations of energy taxation, subsidy-removal and distributive offsets.

Keywords: Distribution, equity, emissions, subsidy

JEL Classification: D12, D31, H23, Q48

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Energy goods are essential to contemporary societies; hence the sizeable expected increase in energy consumption towards mid-century (more than one third, according to projections based on GDP and population trends, e.g. IEA/OECD 2015). In the Americas, Mexico and Brazil are among the developing countries likely to have an important rate of growth in energy consumption and where households will remain a very relevant sector within total consumption. In face of this projected growth, issues such as climate change, energy security, energy poverty, energy price volatility and other environmental concerns constitute important reasons to further study household consumption patterns and energy requirements. In particular, household energy consumption is deeply affected by several public policies that thus bring about significant economic, distributional and environmental impacts.

Mexico is a major oil producer and state-owned *Petróleos Mexicanos* (Pemex) is amongst the largest global oil companies. In 1917, the Mexican constitution established that subsoil resources belong to the country and in 1960 a constitutional amendment banned concessions. Since then, until the recent energy reform, Pemex has been the country's sole producer. This has allowed the government to obtain significant public revenues (Segal 2011). In fact, oil has been the main source of public receipts in Mexico, accounting for over 25 percent of annual government revenues throughout the period 1994-2014 and even reaching 38 percent in 2006 (CEFP 2016). Within this context, the mechanism for determining the tax rate on gasoline consumption, intended to keep prices stable (see PwC 2012), converted this tax into subsidy throughout the period 2006-2014 (except in 2009). Moreover, this subsidy was rather regressive given that fuel expenditure in Mexico is highly concentrated in the richest households (58 percent of the expenditure is generated by 20 percent of the highest-income population; SHCP 2016a). Concerning the electricity sector, although electricity tariffs are high by international standards, a public subsidy program compensates households (Hernández, 2007). The residential electricity subsidy, accounting for 6.3 percent of Mexico's social spending in 2012, is also regressive because higher income households receive a higher subsidy given their higher energy consumption. Notwithstanding, this subsidy may be slightly progressive in rural areas (SHCP, 2016a).

Given this complex and problematic context, in December 2013 Mexico modified its constitution and approved an energy reform that aimed to profoundly transform the hydrocarbons and electricity markets. Triggered by the reduction in oil and gas exploration and production over the previous decade and the increase in electricity prices for both industrial and domestic consumers, this reform focused on increasing oil and gas production. The reform eliminates Pemex monopoly in the exploration, production and transportation of hydrocarbons and increases private participation in the electricity sector (Álvarez and Valencia 2015). It also intends to attract investments and modernize the country's energy sector to promote sustainable economic development (SENER 2015b). The reform has led to the enactment of nine new laws and major changes in the remaining legislation, providing a completely new regulatory framework for the energy sector (Vargas 2015; SENER 2015c). Among the changes affecting taxation on energy products, the mechanism for determining gasoline tax rates was abolished and replaced by fixed tax rates in 2016, with the additional introduction of a carbon tax on fossil fuels in 2014 (see Muñoz 2013)[1].

In terms of the electricity sector, the energy reform aims to reduce production costs and losses in order to reduce tariffs and guarantee the economic sustainability of the institution in charge of the system, the Federal Electricity Commission (see Husar and Kitt 2016). Moreover, as part of its Nationally Determined Contribution (NDC) within the Paris Agreement, Mexico committed to reducing its greenhouse gas (GHG) emissions in at least 25 percent with respect to the 'business as usual' scenario by 2030. The future introduction of an emissions trading system intends to play an important role in the attainment of Mexican GHG objectives, with a compulsory coverage of the electricity sector from 2018. This, together with the aforementioned reasons for sustainable electricity tariffs, is likely to foster a sharp reduction of household electricity subsidies over the next years.

With this backdrop, this paper estimates the household price and income elasticities of demand for different energy goods in Mexico[2] so that different impacts from policy reforms can be

[1] The Mexican system of indirect taxation includes an excise tax, IEPS, applicable to a number of products (including gasoline and LPG, but not electricity) and Value Added Taxation (VAT) with a general coverage of goods. The post-2016 gasoline IEPS is remarkably different to its forerunner that, as previously indicated, acted as a subsidy/tax scheme depending on the evolution of international oil prices. Moreover, a fully regulated gasoline price gave way to a system of national price ceiling from 2015 that was subsequently defined at a regional level (2017) based on international oil prices and Pemex logistical costs. The latter led to sizeable price increases, between 15 and 20 percent in early 2017 (SHCP 2016b), which provoked a significant social unrest across the country. Although the results of this paper show indeed that such price increases will have important effects on consumption and income distribution, they may be mitigated through offsetting transfers to poor households.

[2] Several studies (see Labandeira, Labeaga and López-Otero 2017) have used a demand system to study the demand for energy products, such as Labandeira, Labeaga and Rodríguez (2006) or Romero-Jordán et al. (2010) who are interested in the demand for energy products and for transport fuel, respectively, in Spain; Beznoska (2014) who analyzes energy, mobility and leisure demand in Germany, Bigerna and Bollino (2014) who study consumer behavior in the Italian electricity market, or Chang and Serletis (2014) who deal with the demand for gasoline at Canadian households. In the case of developing countries, this approach have been applied by

properly assessed, including effects on public revenues, emissions and poverty indicators. Although a certain number of papers are devoted to Mexican energy demand[3], to the best of our knowledge, only two studies have attempted to estimate energy elasticities using micro data on household expenses in the framework of a complete demand system[4]. Given the large disparities of lifestyles and energy consumption in Mexico with respect to other analyzed countries, such limited and incomplete academic evidence constitutes a clear shortcoming of the literature because the use of data reflecting individual and household behavior would be able to provide crucial insights on the nature of consumer responses to energy price changes. This is why we adjust a demand system that includes most of the energy goods used in Mexican households and focus on the important socioeconomic factors affecting this demand.

The output of the demand analysis is subsequently used as input for a microsimulation tool to provide a rigorous and detailed economic, environmental and distributional analysis of the real and hypothetical reform packages considered in the paper. Again, the substantial lack of academic (ex-ante) evidence on Mexican energy reforms[5] contrasts with a growing literature, particularly regarding energy subsidy-removal, in several developing and emerging economies[6]. To this end, we have considered three reforms of energy taxation/subsidy removal and different

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Gundimeda and Köhlin (2008) for India, Iootty, Pinto and Ebeling (2009) for Brazil, Ngui et al. (2011) for Kenya, or Sun and Ouyang (2016) for China.

[3] The studies in this area have focused mainly on Mexican demand for transport fuels, such as Berndt and Botero (1985), Eskeland and Feyzioglu (1997b), Galindo and Salinas (1997) or, more recently, Galindo (2005), Crôtte, Noland and Graham (2010), Reyes Escalante and Matas (2010), or Solis and Sheinbaum (2013). For other types of energy, the studies that have been conducted in Mexico are even scarcer: Berndt and Samaniego (1984) analyze the partial income elasticity for electricity, for those with access to it, and the total income elasticity for electricity. Furthermore, Sterner (1989) estimates the price and substitution elasticities of the production factors in the Mexican industry (including electricity and fuel), while Sheinbaum, Martínez and Rodríguez (1996) study residential energy demand (electricity, natural gas and LPG) for the period 1970-1990 and, more recently, Rodríguez-Oreggia and Yepez (2014) analyze the influence of the income level by deciles and the characteristics of the household and the dwelling on residential energy demand.

[4] Renner, Lay and Greve (2017) focus on food and energy with data for the 2002-2014 period, whereas Rosas-Flores et al. (2017) estimate an energy demand system with data for 1994-2010. In both cases they use the results to analyze the effects from changes in energy taxes. Our paper, however, considers a larger (1994-2014) sample, incorporates two conditional demand models on subsamples of households owning and non-owning vehicles (crucial to analyze tax changes that largely affect transport fuels), analyzes de impact of reforms on poverty (including energy and food poverty) and on inequality. Moreover, it covers the recent and sizable changes in the taxation of energy goods.

[5] One recent exception is Arlinghaus and van Dender (2017), who descriptively analyze the impact of the aforementioned tax reforms on transport fuels with respect to a number of policy evaluation criteria. They show that the reform has been successful in tackling environmental external costs, increasing public revenues, and maintaining social acceptability through a gradual approach, although they envision significant equity issues in its future implementation.

[6] For instance, Liu and Li (2011) or Lin and Jiang (2011) evaluate the impact of reducing or eliminating subsidies on different products in China; Solaymani and Kari (2014) study the impact of Malaysia's energy subsidy reform on the economy and the transport sector; Breton and Mirzpour (2016) analyze the impact of the 2010 Iranian energy reform; or Dennis (2016), who uses a computable general equilibrium model to study the effect of eliminating household fossil fuel subsidies in developing countries.

compensatory packages with the most recent wave available of the National Households Income and Expenditure Survey (ENIGH acronyms in Spanish, *Encuesta Nacional de Ingresos y Gastos de los Hogares*[7]) corresponding to year 2014: 1) considering all the taxes on gasoline in place in 2016; 2) eliminating the 2014 subsidy on gasoline; and 3) partially reducing subsidies on electricity. In fact, reforms 1 and 2 could provide valuable insights on the combined effect of tax increases that are currently taking place in Mexico and subsidy removal (real and hypothetical) initiatives. The simulations contemplated in the paper are particularly interesting as they apply to a growing middle-income country with large shares of poverty and high inequality indices. Hence the need to account for the environmental and distributional concerns, as recognized by the three hypothetical and significant compensatory packages included in the simulations that could anyhow be easily implemented through the existing Mexican redistributive devices.

The remainder of this paper is organized as follows. Section I succinctly describes the Mexican energy context and the data. Section II presents the econometric model and the results of its estimation for Mexican households, while Section III shows the results of simulated energy tax reforms and compensatory packages. Finally, Section IV provides the main conclusions and implications of the paper. The details of the data, the theoretical model and additional empirical results are included in three appendices.

I. Mexican energy context and data

Before developing our empirical exercise, it is necessary to describe the setting of Mexico's household energy demand, including its role in overall energy consumption, the relative importance of different energy goods, regional differences, and the issue of energy poverty. Indeed, given a substantial industrial expansion and improved living standards[8], Mexico's energy consumption witnessed an annual growth rate of 1.70 percent between 1994 and 2014 (SENER, 2015a). In 2014 transport accounted for the largest share in total energy consumption (46 percent), followed by industry (32 percent), and residential sector, (15 percent, without

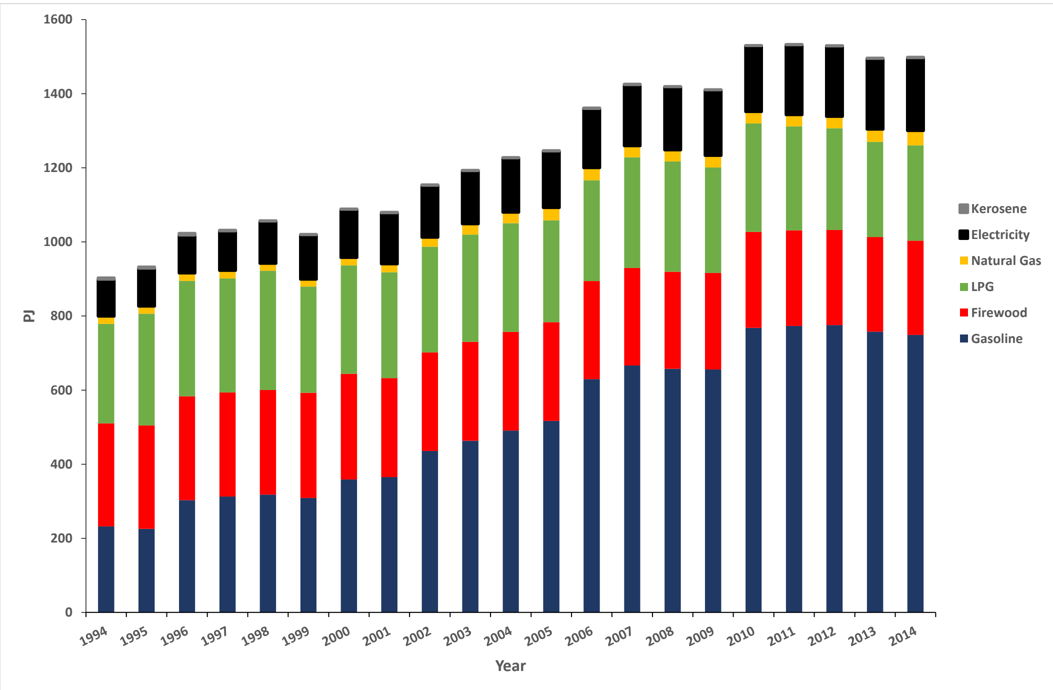
[7] See Appendix A for a description of ENIGH.

[8] Mexican per capita income increased at an annual rate of 3.4 percent between 1994 and 2014 (World Bank, 2016). In 2014, the Mexican per capita income was 10 percent higher than that of Latin America and the Caribbean but well below the level of the US (213 percent higher).

considering transport fuels), for which Liquefied Petroleum Gas (LPG), firewood and electricity constituted the main source of energy consumption.

Figure 1 shows the evolution of the consumption of major energy products at Mexican households for the period 1994 to 2014[9]. As depicted, gasoline (used by almost the entire Mexican automobile fleet) experiences the greatest growth rate over the period, followed by electricity, and their consumption is expected to grow throughout the coming years. Similarly, the shares of LPG and firewood[10] sharply decreased in the period. On the contrary, the weight of petroleum products in the energy consumption mix of Mexican households is well above the product mix in emerging countries like China or India as well as in developed countries, such as the USA or Germany (see IEA 2016b). For its part, the weight of electricity is lower in Mexico than it is in an average developed country, but it is well above that of China or India due to, among other things, widespread access to this form of energy[11].

Figure 1. Residential energy consumption by energy source in Mexico (1994-2014)



Source: SENER (2015a); Solís and Sheinbaum (2013) and our own calculations

[9] Given that no information is available on household gasoline consumption, the reported figures are based on gasoline consumption in road transport provided by SENER (2015a) and the allocation of this consumption by type of vehicle as estimated by Solís and Sheinbaum (2013).

[10] Nearly 28 million Mexicans use firewood as their primary source of energy, especially in rural southern Mexico. In the north a lower reliance in firewood and a larger use of air-conditioners lead to higher household electricity consumption.

[11] Mexican electrification rate was 98.4 percent in 2015 (CFE 2015) due to intense programs to connect rural areas implemented over the last decades.

With respect to energy prices, data from the IEA/OECD (2016) indicate that both in 2014 and 2015 the price of gasoline in Mexico was above USA and OECD average prices, although lower than in other middle-income Latin American countries. It is worth noting that while in many countries gasoline and electricity are subject to significant levies, as advanced in the introduction, both products were subsidized in Mexico at a rate equivalent to 0.4 percent of the country's 2014 GDP: far higher than similar subsidies in China (0.2 percent) but lower than in other developing countries like Venezuela (15.2 percent) or India (1.9 percent) (IEA/OECD 2015).

The singularity of the Mexican household energy domain, just depicted, thwarts the extrapolation of existing international academic evidence and vindicates our empirical exercise. Indeed, to analyze energy demand we have extracted the data on household consumption expenditure from ENIGH for 1994-2014. We select five different goods to estimate demand: food, electricity, LPG, gasoline, and other non-durable goods, representing all expenditure on non-durable goods[12]. For the sake of avoiding complications arising from the investment nature of durables, we do not consider durable goods within the expenditure categories. We chose to aggregate the rest of the non-durable goods to attenuate the impact of the presence of null expenditure on multiple non-durable goods and thereby solve this problem. Nevertheless, we take account of zeros in some groups and also estimate the model under alternative assumptions. We took the prices from the annual average of monthly price indices by city, provided by the National Institute of Statistics and Geography (INEGI per its name in Spanish, *Instituto Nacional de Estadística y Geografía*), and converted them into real terms using the retail price index[13]. We also included a series of variables on household, individual and residence characteristics that attempt to capture differences in tastes. Thus our database consists of 124,771 observations but, to reduce heterogeneity among the different households, we restricted our analysis to the following definition of household categories: single; main contributor to income and husband/wife and/or children and/or relatives. After transforming, filtering and further selecting the data by dropping the households in the first and the last

[12] Table A1 in Appendix A enumerates the variables used in the model.

[13] INEGI provides price indices for 46 cities, which we have assigned to the 32 federative entities as follows: for the states that have information only on one city, we considered the prices of the city and applied them to the whole entity; for the states with information on multiple cities, we considered the average price indices of these cities and applied them to the whole federative entity (except for cities in which their own index is considered).

percentiles of total spending on non-durables and income, as well as households with zero food expenditure, we kept a final sample size of 119,406 observations for the estimation.

The share of expenditures in Mexican households throughout the period 1994-2014 (see the left side of Figure A1 in Appendix A) shows that food has the highest weight in their basket, followed by gasoline, electricity and LPG. The figure shows that the share of gasoline expenditure has virtually grown continuously throughout the period, with a remarkable stability in electricity and LPG shares, while the share of food decreased until the year 2006, only to rise thereafter[14]. However, these budget shares vary both across different regions of the country as well as from urban to rural areas[15]. Indeed, urban households devote a share of their expenditures to energy products well above national averages. Moreover, households in the southern region devote a higher (lower) share of their expenditures to food (energy goods) with respect to national averages. Households in the northern region show the opposite profile, whereas the central region presents percentages akin to the national average.

Household income variation within the country could explain some of the differences in the aforementioned expenditure structure. Indeed, as advanced in the introduction, Mexico is a country with sizeable income differences and an important share of its population lives in deep poverty (see Hammill 2005). Regarding the distribution of equivalent income by deciles, in 2014 2.2 percent was available to the first decile while 36.4 percent was concentrated in the last one[16]. If we calculate the poverty rate, defined as the percentage of households living below the poverty line (see Foster, Green and Thorbecke 1984), with the poverty line being equivalent to 60 percent of the median income (Heindl 2015), we obtain that 22.1 percent of Mexican households were in poverty in 2014. Although households in the southern (poorest) region represented 22.3 percent of Mexican households in 2014, they accounted for 44.7 percent of

[14] The right side of Figure A1 depicts the evolution of energy products and total per capita expenditure (as an income proxy), showing a similar evolution of the price and expenditure share of food while energy products present no such clear pattern.

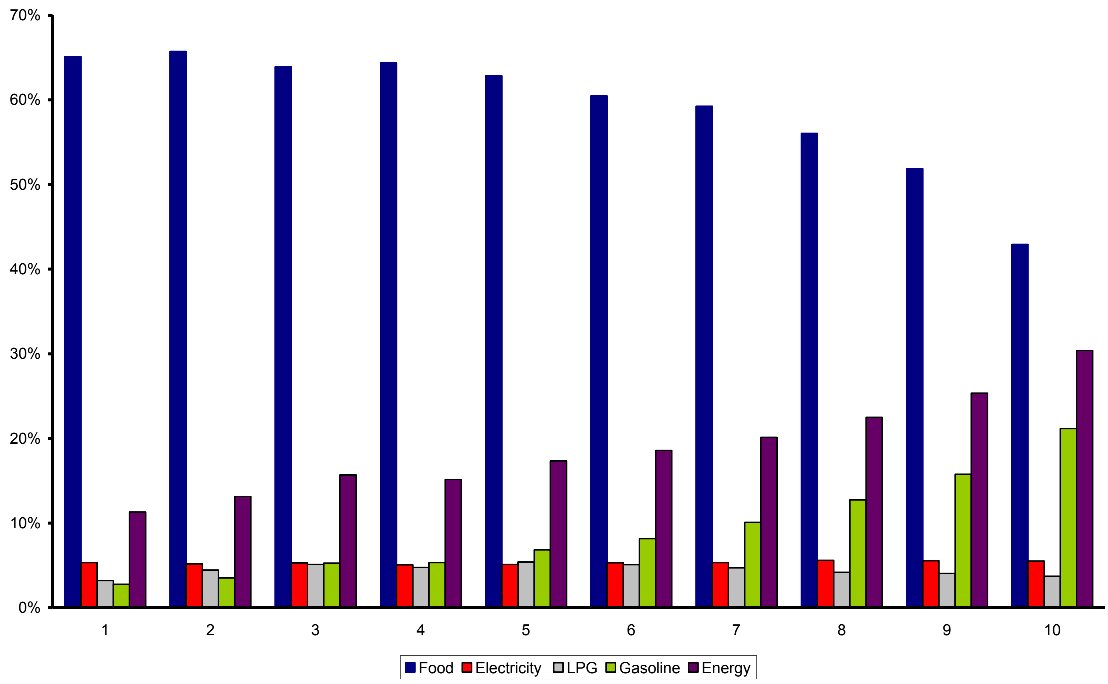
[15] The northern states are Baja California, Baja California Sur, Coahuila, Chihuahua, Durango, Nuevo Leon, Sinaloa, Sonora, Tamaulipas and Zacatecas; the states of the central region are Aguascalientes, Colima, Mexico City, Guanajuato, Hidalgo, Jalisco, Mexico, Michoacan, Morelos, Nayarit, Puebla, Queretaro, San Luis Potosi and Tlaxcala; while the states of Campeche, Chiapas, Guerrero, Oaxaca, Quintana Roo, Tabasco, Veracruz and Yucatan comprise the southern states. We consider rural (urban) households as those living in municipalities under (above) 2,500 inhabitants.

[16] Equivalent income is calculated using the equivalence scale of CONEVAL (2014), which weights the first adult household as 1, the remaining adults (>18 years) as 0.99, 0.71 for people between 13-18 years of age, 0.74 for people aged 6-12 and 0.70 for people aged 0-5.

the households in the first decile of income per capita and only 15.4 percent of households in the last decile[17]. Poverty rates are also very different in rural and urban areas.

With the preceding information, Figure 2 shows the well-known fact that as income increases the proportion of expenditure on food (energy) decreases (increases). Among the energy products, the percentage of spending on LPG increases up to the fifth decile and then falls, even though the percentages are similar across the distribution of income. The weight of spending on electricity is very similar in all deciles, while gasoline shows a growth profile with respect to income and differs significantly among rich and poor[18].

Figure 2. Share of expenditure on food and energy by deciles of equivalent income. 2014



Note: Energy is the sum of electricity, LGP and gasoline
Source: Own calculations based on ENIGH and INEGI data

Since the paper contemplates reform packages that intend to tackle poverty, particularly energy poverty, we next provide a brief description of this issue. First we consider the usually employed 10 percent threshold, which defines households as being energy poor when their energy costs

[17] By contrast, the northern region (25.8 percent of households) and the central region (51.9 percent) have a percentage of households in the first decile (16.7 percent and 38.6 percent, respectively) lower than at the aggregate level and a higher percentage of households in the last decile (27.1 percent and 57.5 percent, respectively).
[18] This is obviously related to varying access to vehicles (car, van or motorcycle): only 17.1 percent of the poorest have a vehicle as compared to 75.9 percent of the richest households.

are above 10 percent of their income (Boardman 1991). Table 1 reports that 25.8 percent of Mexican households spent more than 10 percent of their income on energy fuels in 2014[19], with a slight difference among rural and urban households. However, this indicator has been widely criticized because it does not consider the level of household income and hence does not capture one of the main determinants of energy poverty (Hills 2011)[20]. We therefore contemplate two indicators of energy poverty that account for the level of household income: the After Fuel Cost Poverty (AFCP) and the Minimum Income Standard (MIS).

The AFCP (Hills 2012) considers a household to be fuel poor if its equivalent income (without energy costs and housing) is below 60 percent of the equivalent average income (without energy costs and housing) for all households[21]. At an aggregate level, the outcome of this measure is similar to the one obtained through the preceding alternative. However, if we distinguish between area and region of residence of the household, results vary: Table 1 shows that energy poverty is much higher in rural than in urban households and it is also higher in the poorest (southern) region.

The MIS (Bradshaw et al. 2008) is defined as the necessary income for attaining the opportunities and choices required to participate in society[22]. The measure considers any household with a level of income below its MIS (once energy and average housing expenditures have been discounted) to be energy poor. The MIS Mexican results for 2014 depict higher levels of energy poverty than with the preceding measures and, as with AFCP, the percentage of fuel poverty in households in the northern and central (southern) regions and urban (rural) areas are below (above) the national average (see Table 1)[23].

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19 We have considered energy expenditure on electricity, LPG, gasoline, natural gas, oil, diesel, coal, firewood, heating fuel and other fuels.

20 Additionally, the indicator is also very sensitive to changes in energy prices (Moore 2012). Indeed, if we look at this indicator by region, we see that the southern region presents a lower energy poverty indicator despite being the poorest.

21 Housing costs are the variable rent estimations of the ENIGH, which considers the estimated rental value that the household would have to pay on the market to have accommodation of the same size, quality and location.

22 This measure links the level of household income, after making basic necessary payments (energy and housing), to the income level required to 'participate' in society. MIS is thus more consistent with the ability of a household to meet its energy costs (Moore, 2012)

23 We consider as MIS the line of wellbeing calculated by CONEVAL (2015), which incorporates the value of food basket and non-food basic consumption of one person per month, distinguishing between urban and rural households. To take household size into account, we calculate the MIS equivalent multiplied by the scale of equivalence of CONEVAL (2014).

Table 1. Share of Mexican households in energy and food poverty. 2014 (%)

	Energy Poverty			Food Poverty
	10	AFCP	MIS	
Mexico	***25.82***	***22.45***	***32.61***	***11.09***
North	45.46	19.59	29.40	6.55
Center	20.19	19.24	31.04	8.80
South	16.29	33.07	39.89	21.56
Urban	26.41	16.53	30.53	8.31
Rural	23.71	43.92	40.15	21.19

Source: Our own calculations based on ENIGH and CONEVAL (2015) data

Finally, given the large negative impact of food price increases on the living conditions of poor households in several regions across the country (see Attanasio et al. 2013), we also deal with food poverty in Mexico. In line with CONEVAL, food poverty is defined as the inability to purchase a basic basket of goods even if the household devotes all of its disposable income to it. We therefore calculate the equivalent basket of food commodities using that definition and the equivalent scales of CONEVAL (2014) and compare it with total household income. According to the results obtained using data from ENIGH for 2014, reported in Table 1, around one tenth of Mexican households are in food poverty. Again, important differences arise when looking at the results by region and rural/urban households.

II. An energy demand system for Mexico

II.A. Econometric model and estimation method

The advantage of the system approach, applied in this paper, over the single equation approach rests in its consideration of the interdependence of budget allocations for different goods. Such a framework may therefore provide essential information concerning the sensitivity of household energy demand relative to price changes and the expenditure of products contained in the basket of household goods, as well as interdependences between energy types at this level. It is also crucial to explicitly have food in the system since its share accounts for the most relevant component of the budget of Mexican households. Moreover, our system includes expenditure on all non-durable goods.

The chosen model, the Quadratic Almost Ideal Demand System (QUAIDS), is an extension of the Almost Ideal Demand System (AIDS) originally proposed by Deaton and Muellbauer (1980). Based on a non-parametric analysis of consumer expenditure patterns, Engel curves have been shown to be of higher rank than two, thus requiring quadratic terms in the logarithm of expenditure (a result also supported in this paper, as seen in Appendix A). Further, Banks, Blundell and Lewbel (1997) stated that models failing to account for Engel curvature generate distortion in welfare measures when they are calculated after the adjustment of demand functions. Previous models such as the AIDS did not consider this issue and only used linear terms in total expenditure in the demand equations. The QUAIDS extends the AIDS model with a quadratic logarithm of expenditure that allows for more flexible responses. Since this model has become popular in adjusting demand systems, we relegate its details to Appendix B and concentrate, herein, on the main challenges to estimating the model.

The first problem we face relates to the presence of zero expenditure on some goods with consequences for the properties of the estimated parameters. Selecting the sample on the positives only allows us to estimate conditional effects (Deaton 1990) but it has other upshots when the selection is endogenous. A widely-employed solution to the censoring problem is the use of a tobit-type approach (Tobin 1958; Amemiya 1984), extensively employed in single-equation demand models but rarely used in demand system estimation because when zeros arise in more than three goods it requires the use of simulated methods (see Hajivassiliou and McFadden 1998). Several estimation proposals have been employed to deal with the difficulties, the first of which was noted by Wales and Woodland (1983) and Lee and Pitt (1986)[24]. The logic behind this approach resides on determining if the zeros arise because of corner solutions. When zeros are due to non-participation, we may consider a two-stage decisions model (i.e., tobit-type 3 in the terminology of Amemiya 1984). We develop this approach further in Appendix B since the zeros in the considered group (gasoline) of our application are mainly due to the non-owning of cars by households, not to corner solutions.

[24] Subsequent applications include Kao, Lee and Pitt (2001), Yen, Lin and Smallwood (2003) and Yen and Lin (2006), among others.

We purpose to estimate an unconditional demand system that does not account for any correction for the presence of zero records, and two conditional demand models on subsamples of households owning and non-owning vehicles. The process for the conditional alternatives are implemented through the estimation of a probit model in the first stage and the calculation of the Inverse Mills Ratio (IMR) which, in turn, is used to correct the budget share equations of all goods at a second stage. We need the estimated parameters for the whole population to simulate the proposed reforms, so we estimate the equations for owners and non-owners (i.e., we employ a kind of Roy model as described, for instance, in Cameron and Trivedi 2005).

A second problem, commonly found in survey data, concerns the measurement errors in expenditure variables. Since the recording period is short (two weeks), infrequency of purchase is due to purchases of some goods not recorded during that time span. Of course, this does not exclude the presence of measurement errors arising from household reports of misleading information for some goods. In any case, total expenditure takes the errors along since it is created by aggregating expenditures on all the goods contained in the system. Under this circumstance, total expenditure becomes endogenous in the budget share equations and the presence of endogeneity renders inconsistent parameter estimates. We may address this issue using instrumental variables (Blundell and Robin 1999), thus facing a non-linear model whose equations should be estimated simultaneously to enforce the cross-equation restrictions imposed by the theory. Yet, instead of applying non-linear instrumental variables in three stages, we follow Blundell and Robin (1999) and apply iterative linear least-squares (ILLS) given that the almost-ideal demand models are conditionally linear. For given values of price aggregators, expression (B3) in Appendix B, we estimate the parameters of equation (B4) iteratively using a linear moment estimator and we perform a Seemingly Unrelated Regression (SUR) within each iteration. Once we account for endogeneity of total expenditure this SUR method is theoretically identical to three-stage least squares. At this estimation process we impose the restrictions. Since the intercept of the price aggregate in expression (B3) is not identified, we follow Deaton and Muellbauer (1980), who propose using the lowest value of the log of total expenditure in the data. Concerning the theoretical restrictions, adding-up is accommodated by dropping one of the equations, which at the same time avoids the singularity of the variance-covariance matrix of the errors. Symmetry and homogeneity are imposed during estimation: symmetry is a cross-equation restriction, whereas homogeneity is essentially a within-equation restriction (see Appendix B for more details).

II.B. Results

II.B.1. Fuel demand determinants

Tables C1-C3 (Appendix C) report the results of the estimated parameters. The need for a rank three system is confirmed by the significance of the quadratic terms in log expenditure. The electricity results indicate that domestic equipment, electricity price, the price of other goods, geographical location and some socio-economic variables (such as age, gender and the education level of the head of the household) are key factors to explain the electricity budget share. However, differences are observed between households owning vehicles and those that have no vehicle. The coefficients of the regional dummy variables imply that, with other factors remaining constant, the electricity budget share of the people in the north and in the center of the country is relatively low in households owning a vehicle. This may be explained by the relatively high level of income in those regions. Nonetheless, the budget share of electricity of households not owning a vehicle is relatively higher in the center of the country as economic progress may have led to an increased use of electrical appliances there[25]. Total income, geographic location, education and household vehicle ownership are the main drivers of the share of gasoline expenditure. The magnitude of the share of the gasoline budget is greater for households in northern Mexico than for the rest of the households. The socio-economic tissue of this zone may account for this as well as the longer distances driven in the North as compared to the rest of the country.

Household composition also affects the expenditure on required energy. Every additional senior member represents a reduction in the share of electricity, LPG and gasoline; while every additional child represents a reduction in the budget share of LPG and gasoline. These results reflect the (impure) public nature of the energy goods within the household. Moreover, our results reveal that geographical location plays a role on the demand of LPG and gasoline. Urban households owning a vehicle have a higher share of LPG than do those corresponding to rural zones. On the other hand, people in the south have the lowest LPG and gasoline budget share, possibly given the poverty rate of this area.

[25] As hinted in Section I, the geographic inequality marks economic development in Mexico: both northern and central Mexico have the highest human development index, nearly at a developed-country level, while the southern states are well below this situation. Geographic dummies and their interaction terms with income indicate that the magnitude of the effect of income on all budget shares differs among households located in northern Mexico and those located elsewhere.

In addition, we have tried to capture different effects of total expenditure by age, area or residence and level of education. We find that, for most of the goods, these three variables show additional non-linear income effects that are heterogeneous across goods. For instance, a higher level of education corresponds to a lower effect of income on the demand for food and a higher effect of income on the demand for electricity. This is particularly the case of households owning a vehicle (car, van and/or motorcycle). All in all, we feel that these results gather the impact of economic and socio-demographic variables as well as the heterogeneity of behavior, which will be remarkably relevant in the implementation of the contemplated tax reforms.

II.B.2. Elasticities

Table 2 shows the results of expenditure and Marshallian own-price elasticities[26]. Food, LPG and gasoline are luxury goods; while the other goods are estimated as normal goods. Our results for gasoline are similar to the findings of Olivia and Gibson (2008) but they contrast with those reported by Eltony and Al-Mutairi (1995) for Kuwait and those of Crôtte, Noland and Graham (2010) for Mexico, although these articles employed aggregate data. Mexican studies employing micro data also identify gasoline as a luxury commodity (Renner, Lay and Greve 2017), although this paper and Rosas-Flores et al. (2017) provide lower income elasticities, which may be related to their more imperfect representation of Mexican reality (see Section II.A). Attanasio et al. (2013) also find, with ENIGH data, that several of the commodities entering the food group are luxuries for Mexican households. Electricity, for its part, shifts from being a normal good for households owning a vehicle to being a luxury good for households not owning a vehicle. The relatively high levels of income in the former type of household could account for this. Furthermore, while expenditure elasticities of food and LPG are rather similar for both types of households, the effects on other non-durable goods differ substantially in households not owning a vehicle, more sensitive to income changes.

[26] We also calculated Hicksian-compensated price elasticities, which we do not report in the paper. However, they are available upon request.

Table 2. Expenditure and Marshallian own-price elasticities

	Food	Electricity	LPG	Gasoline	Other non-durables
Conditional on owning a vehicle					
Expenditure	1.063 (0.037)	0.654 (0.110)	1.179 (0.126)	1.863 (0.087)	0.296 (0.066)
Own-price	-0.757 (0.040)	-1.911 (0.041)	-0.991 (0.087)	-0.907 (0.081)	-0.945 (0.058)
Conditional on non-owning a vehicle					
Expenditure	1.137 (0.018)	1.124 (0.066)	1.101 (0.085)	--	0.681 (0.035)
Own-price	-0.468 (0.018)	-1.189 (0.031)	-0.915 (0.082)	--	-0.251 (0.034)
Unconditional demand system					
Expenditure	1.009 (0.013)	0.749 (0.040)	1.297 (0.055)	1.592 (0.055)	0.861 (0.023)
Own-price	-0.690 (0.021)	-1.520 (0.024)	-1.179 (0.054)	-0.904 (0.051)	-0.278 (0.029)

Note: Standard errors in parentheses

The Marshallian own-price elasticities show that, while food[27] and gasoline are price inelastic, electricity is price elastic. LPG is price elastic in the unconditional model, although price inelastic in the conditional model with values close to one. Important differences are present between households that are owners and non-owners of vehicles in the conditional model. Households with a vehicle are more sensitive to price changes in all goods. Yet the values of price elasticity of electricity demand indicate a high sensitivity of households towards price changes, regardless of whether they own a vehicle. Given that household electricity consumption is heavily subsidized in Mexico, a total or partial elimination of these subsidies and subsequent price increase would have relevant impacts on electricity demand. We additionally find that all the households in the sample have an inelastic response toward gasoline price changes, although the absolute values of their price elasticity are very close to 1. These results concur with Eskeland and Feyzioglu (1997a) with aggregate data and also with those obtained by Renner, Lay and Greve (2017). However, they are higher (in absolute value) than those reported by Rosas-Flores et al. (2017), which may be due to the lower reliability of an AIDS model to deal with Mexican energy demand (see Section II.A).

As hinted before, LPG, with around 30 percent of zero observations up to 2000 and between 40 percent and 50 percent since then, is a problematic good within our demand system. Given that

[27] A similar result is found in most of its components by Attanasio el al. (2013),

individuals could take decisions both at the extensive and intensive margins, in these circumstances it is necessary to use a different model and have opted for a simultaneous tobit demand system that is estimated by maximum likelihood (ML, see Kao, Lee and Pitt 2001). Since there are only two goods subject to censoring, the ML can be obtained by simply evaluating a bivariate normal distribution without the need to use any method of simulated moments. We also instrument total expenditure to allow for measurement errors. So, we estimate the model to test whether the elasticities are in the range of those presented in Table 2. Total expenditure elasticities in an unconditional simultaneous tobit framework for food, electricity, LPGs and gasoline are, respectively, 0.903, 0.910, 0.992 and 1.767. Own price elasticities for the preceding four goods are, respectively, -0.760, -1.459, -1,691 and -0.538.

III. Simulating energy tax reforms, subsidy removal and distributional compensations

We propose simulations for three tax reforms on energy products, summarized in Table 3, using the results of the conditional demand model. The first reform considers introducing the 2016 gasoline tax in 2014, while the second one analyzes the impact of eliminating the subsidy on gasoline in 2014 (consequent to the mechanism for calculating the IEPS). Finally, the last reform reduces electricity subsidies in 2014; hence it is the only fully hypothetical (but likely) scenario. The sample employed for assessing all reforms is the 2014 wave of the ENIGH. In each case the results provide valuable socio-economic and environmental information: effects on household tax payments and on government revenue as well as the impact on energy demand and carbon dioxide (CO_2) emissions[28].

Given that, besides providing a detailed distributional analysis of energy tax changes and subsidy removal in Mexico, a major objective of this paper is to analyze the effects of the proposed reforms on poverty alleviation (and on food and energy poverty in particular), Table 3 includes the revenue-recycling alternatives[29]: 1) Transferring an equal lump sum to all

[28] Even though Mexico suffers important local pollution problems, it is difficult to evaluate changes in local emissions to modified energy consumption (related to the simulated reform packages). In any case, although not assessed in the paper due to data limitations, it is clear that there would be an additional 'local' environmental co-benefit from the introduction of the contemplated reforms.

[29] As shown by Gago, Labandeira and López-Otero (2014) other recycling options, such a tax shifts and/or environmental expenditure increases, have been usually implemented by green tax reforms in the real world. Yet, given the Mexican socio-economic context and the objectives of the paper, we decided to return all revenues to households to explore the overall distributional outcome of different policy packages.

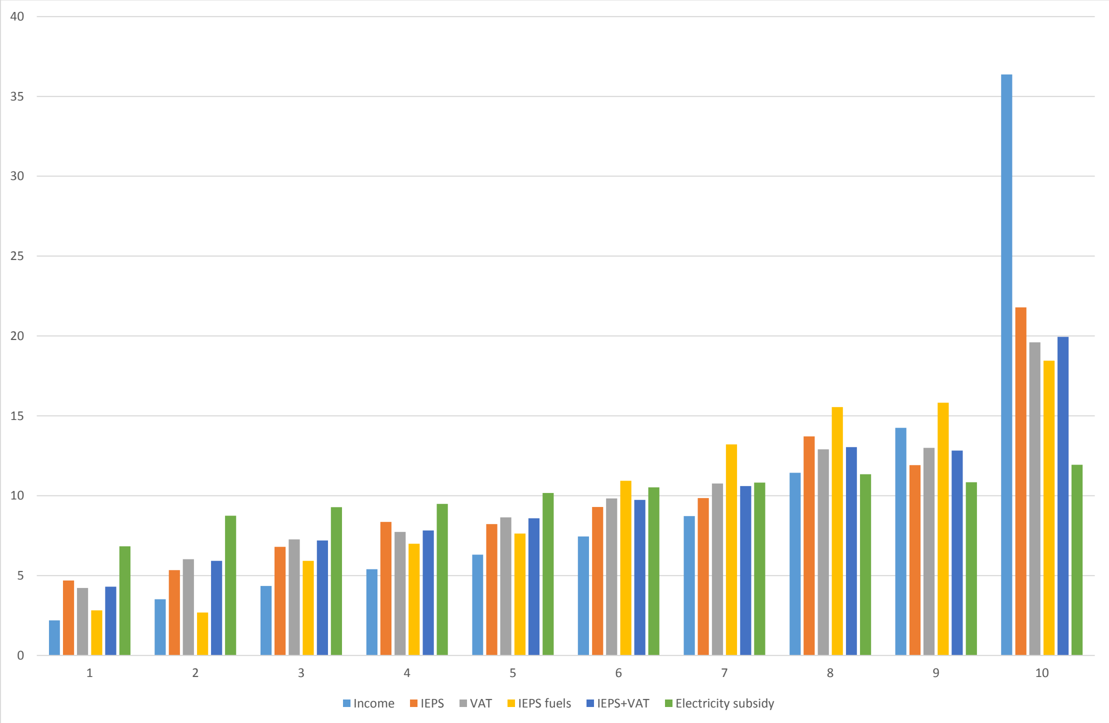
households; 2) transferring a lump sum only to households in poverty (in an equal amount for all of them); 3) transferring an amount inversely proportional to the equivalent level of household income conditional on being in poverty. These recycling alternatives could be easily carried out through current Mexican poverty-combating programs like PROSPERA or DICONSA (see SEDESOL 2015).

Table 3. Hypothetical reforms used in the simulations

<table>
<tr><th></th><th></th><th>Initial situation
(IS)</th><th>Reform 1
(new gasoline tax)</th><th>Reform 2
(removal of gasoline subsidy)</th><th>Reform 3
(partial removal of electricity subsidy)</th></tr>
<tr><td rowspan="3">Gasoline</td><td>General IEPS</td><td>Subsidy</td><td>Low Octane: 4.16 pesos/l
High Octane: 3.52 pesos/l</td><td>0</td><td>Idem to IS</td></tr>
<tr><td>Carbon IEPS</td><td>0.104 pesos/l</td><td>0.111 pesos/l</td><td>Idem to IS</td><td>Idem to IS</td></tr>
<tr><td>IEPS Federative Entities</td><td>Low Octane: 0.36 pesos/l
High Octane: 0.439 pesos/l</td><td>Idem to IS</td><td>Idem to IS</td><td>Idem to IS</td></tr>
<tr><td>Electricity</td><td>Subsidy</td><td>Subsidy</td><td>Idem to IS</td><td>Idem to IS</td><td>Reduction of 33.3 percent in the subsidy to the four highest income deciles</td></tr>
<tr><td>Revenue use</td><td></td><td>0</td><td colspan="3">1/ Equal lump-sum
2/ Lump-sum to households in poverty
3/ Transfer to households in poverty (inversely proportional to income)</td></tr>
</table>

Before presenting the results of the reforms, we calculate tax payments by households at the baseline scenario using the expenditure data from the ENIGH and represent them in Figure 3. The figure depicts a rather regressive tax situation in the baseline due to the impacts of VAT and IEPS: the income weight of all the deciles of income (except for the last two deciles) is lower than the percentage represented by their contribution to IEPS and VAT taxes. Indeed, the 10 percent of richest households have 36.4 percent of the equivalent income but they only contribute 19.9 percent of total revenue arising from the two taxes. The subsidy for residential electricity is also very regressive because it grows as household income increases. While the 10 percent poorest households receive 6.8 percent of the electricity subsidy, the 10 percent richest households receive 11.9 percent.

Figure 3. Distribution of equivalent income and tax payments/subsidies by deciles of equivalent income in 2014 (percent)



Note: IEPS fuels considers the on-going collection of the IEPS tax applied to fuel, i.e., the general IEPS, carbon IEPS and the IEPS for the federative entities.

We simulate the effects of each reform by first calculating the pre-reform tax payments on VAT and IEPS for each household from its expenditure on non-durable goods. We then aggregate household tax payments using the grossing-up factors (number of households in the population represented by each household in the sample) to obtain the initial revenue obtained by the government (R^0),

$$R^0 = \left[\sum_{i=1}^{N} g_i \sum_{k=1}^{K} \frac{t_k^0 p_{ki}^0 q_{ki}^0}{1+t_k^0}\right] \qquad (1)$$

where the first sum extends to all households in the sample (*N*) and the second to all the considered goods (*K*). t_k^0 is the pre-reform tax rate of good *k* (we assume that it includes both the VAT and IEPS to keep notation simple) and p_k^0 and q_k^0 are, respectively, the pre-reform price and pre-reform quantity demanded. Post-reform revenue can be calculated using equation (1) in the same way but substituting prices, quantities and tax rates by their post-reform values. When behavior is not considered, only prices and tax rates change, whereas $q_k^0 = q_k^1;\ \forall k$.

In the case of electricity, we calculate the initial electricity subsidy following the procedure described in Komives et al. (2009) using the information provided by the ENIGH along with the fee structure and climatic information. In addition, we assume a complete pass-through of tax changes to consumers and no change of household total expenditure. When consumers react to price changes, we impose the estimated parameters of the demand system. So, to calculate post-reform tax payments, we predict the expenditure shares at the new prices and we compute expenditure on each good from these predictions. The post-reform tax payment of household *i* for good *k* is $\frac{t_k^1 p_{ki}^1 \hat{q}_{ki}^1}{1+t_k^1}$, with super-index 1 representing post-reform values and $\hat{q}_{ki}^1$ denoting the predicted value of quantity demanded for good *k* by household *i*. The post-reform tax revenue, when behavior is considered, can then be expressed as,

$$R^1 = \left[\sum_{i=1}^{N} g_i \sum_{k=1}^{K} \frac{t_k^1 p_{ki}^1 \hat{q}_{ki}^1}{1+t_k^1}\right] \qquad (2)$$

Once we have the new shares (and quantities) it is possible to calculate the impact of the reform on energy consumption by just comparing pre-reform with post-reform quantities and thus also the effects on CO_2 emissions. Pre-reform emissions are computed by using the initial amounts of gasoline and LPG with the average prices of these products in 2014 (in the case of electricity, the initial amounts are obtained when calculating the subsidy) and compared to post-reform emissions (with post-reform amounts and prices)[30]. The information on the increase in tax revenue, together with the grossing-up factor, allows us to obtain the cash transfer that each household will receive with the contemplated recycling options. The cash-transfer is added to the income of the household to get the new income variable, which we then use to calculate the new equivalent income and the new poverty rate. In order to calculate food and energy poverty indicators, we use new household income and food/energy expenditures at new prices.

III.A. Reform 1 (new gasoline tax)

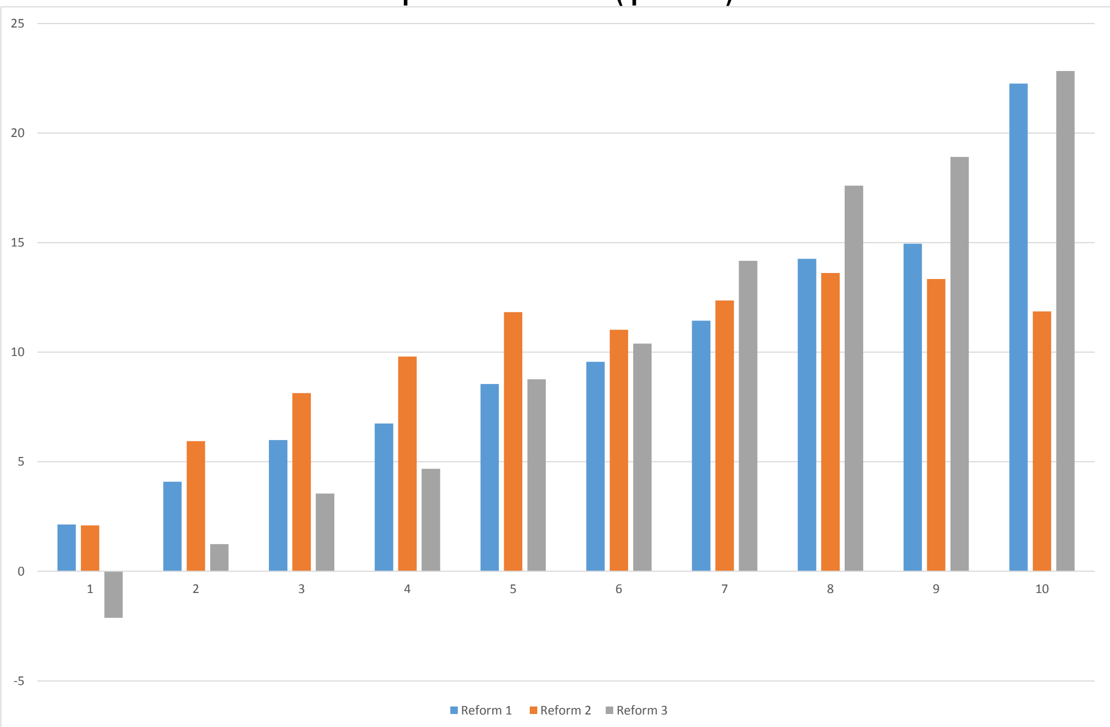
The 'morning-after' effects of this reform represent an increase of 336.2 percent in revenue from the IEPS and a 10.1 percent increase in revenue from VAT, with an overall increase of government revenue from the new taxes of 61.7 percent. Yet the second-round effects, once

[30] We convert consumption to emissions using the emission factors from INECC (2014) for gasoline and LPG, and the IEA (2016a) emission factor for electricity in Mexico.

behavior is accounted for, provide an increase in total government revenue of 44.6 percent (40,477 billion pesos or 3,045 billion US$, which accounts for 0.23 percent of the GDP). This corresponds to a 239 percent increase in revenue from IEPS and a slight 8.1 percent increase in VAT receipts.

The distribution of total tax payments (additional government revenue) by income deciles provides a picture of a very progressive reform (see Figure 4). Over 22 percent of the additional revenue would come from the highest income decile, and over 50 percent of it would come from the three highest income deciles. Concerning its effect on energy consumption and CO_2 emissions, the reform would reduce household energy consumption by 26 percent, allowing for a 19.1 percent reduction of carbon emissions. The impact on consumption and emissions mainly affects rich households, so the highest income decile contributes 22 percent of the reduction in energy consumption (22.4 percent in carbon emissions). Conversely, the lowest income decile only contributes 2.9 percent of the reduction in energy consumption (2.1 percent in carbon emissions).

Figure 4. Distribution of the additional tax revenue from the reforms by deciles of equivalent income (percent)



Note: We consider the additional tax generated by the total IEPS and the VAT.

This progressive impact confirms the results obtained by Sterner and Lozana (2012) or Renner, Lay and Greve (2017), who found that a tax on the direct use of fuel (or a CO_2 gasoline tax in the case of Cespedes 2013) in Mexico would be strongly progressive; by Abramovsky and Phillips (2015), who found that the Mexican tax reform of 2010 (increased VAT rate together with minor changes in income and excise duties) was progressive when spending was used as a measure of the standard of living; by Huesca and López-Montes (2016) who indicated that Mexican gasoline taxes tend to be borne by households with higher incomes; or by Rosas-Flores et al. (2017), who showed that Mexican gasoline subsidy was noticeably regressive[31]. On the other hand, as shown by Renner, Lay and Greve (2017) for Mexico, or by Durand-Lasserve et al. (2015) for Indonesia, the redistribution of tax revenues to households is more progressive and more effective in reducing poverty rates, especially if it only targets the poorer households. Finally we obtain the usual result in the literature: the reforms lead to reductions in energy consumption and, consequently, in CO_2 and other fossil-fuel related emissions[32].

II.B. Reform 2 (removal of gasoline subsidy)

In this case, the immediate short-term effects of the reform consist in a 39.3 percent increase in revenue from IEPS that, together with a small increase in revenue from VAT (1.2 percent), represents an overall increase of 7.2 percent in total government revenue. However, as in the preceding reform, these figures correspond to an upper threshold given the reaction of households to different relative prices. Second-round effects thus lead to a 28 percent increase in revenue from IEPS, 7.1 percent increase in revenue from VAT and 10.4 percent increase in total government revenue (9.43 billion pesos or 0.71 billion US$, 0.05 percent of Mexico's GDP).

Regarding the distribution of tax payments by deciles of equivalent income, this reform is less progressive than the previous one. The highest income decile contributes less than 12 percent of the additional revenue and the three richest deciles contribute less than 40 percent. Meanwhile, household energy consumption falls by 12.7 percent, and the associated CO_2

[31] Note that these results do not consider the potential regressive 'indirect' effects of a gasoline tax through price increases of goods that are particularly used by poorer households, such as public transportation (see Pizer and Sexton 2017). However, revenue recycling could mitigate these negative effects (see Section III.D).

[32] Although not explicitly assessed in this paper, this is a common finding in the literature (see, e.g., Lin and Jiang 2011; or Solaymani and Kari 2014).

emissions decrease by 5.7 percent. With respect to the previous reform, now the poor contribute more to reducing consumption and associated emissions[33].

It should be noted that reforms 1 and 2 are closely related. Results from reform 1 can be interpreted as arising from the decomposition of two effects: the abolition of the subsidy (reform 2) and the tax increase. Taking this into account, the impacts of reform 1 mainly derive from the tax increase, since only 23.3 percent of the expected increase in revenue from the first reform is brought about by the elimination of the subsidy. In terms of the impact by deciles, the tax increase is more progressive than the suppression of the subsidy as, with the tax increase, the richest decile contributes 25.4 percent of the additional revenue and the three richest deciles contribute 55.3 percent of the new receipts (as compared to 11.9 percent and 38.8 percent, respectively, in reform 2). On the other hand, the tax increase has a greater impact on the first reform in terms of energy consumption and emissions, leading to 51.2 percent of the reduction in energy consumption and 69.9 percent of the reduction in carbon emissions.

III.C. Reform 3 (partial removal of the electricity subsidy)

The direct, no-reaction or 'morning-after', effects of this reform lead to a small increase in revenue from VAT (3.1 percent) and to a reduction of the total resources allocated to the electricity subsidy by 16.3 percent. However, if we take the response of consumers to the reduced electricity subsidy into account, the reduction of the total amount of electricity subsidy rises to 28.2 percent. This, together with the 3.7 percent VAT revenue increase, generates additional 28,864 million pesos (2,171.5 million US$), equivalent to 0.17 percent of Mexico's GDP in 2014. The reform would be indeed very progressive, as the highest income decile contributes 22.8 percent of this amount. As for energy consumption, the reform reduces the consumption of the three main energy products by 12.4 percent and their associated emissions by 10.2 percent. For equivalent income deciles, the 10 percent richest (poorest) households contribute 19.3 percent (4.4 percent) of the reduction in consumption and 20.4 percent (2.7 percent) of the reduction in emissions.

[33] The lowest (highest) income decile reacts to the reform by reducing energy consumption by 4.2 percent (18.4 percent) and consequently lowering its emissions by 2.9 percent (16.2 percent).

III.D. Effects of the simulated reforms on poverty

In this section we deal with the effects of recycling the extra-revenue obtained from the abovementioned tax reforms under the three different transfer schemes previously indicated. The first reform with the first transfer scheme, allows for a lump-sum transfer of 1,668 pesos (125.5 US$) to each household per year (as in every case from now onwards), thereby managing to slightly reduce the percentage of households in poverty (see Table 4). The extra-revenue available under the second alternative would provide a cash transfer of 7,564 pesos (569 US$) to each household in poverty. This would reduce the poverty rate to 17.3 percent, and the poverty in the (poorest) southern region would fall below 30 percent. Finally, the third recycling option would involve transferring the additional revenue to households in poverty in an amount inversely proportional to their income level. Thus, each household in poverty would receive a different amount in function of its income level, ranging from 4,843 to 50,041 pesos (364.3 to 3,764.7 US$), thus reducing the poverty rate to 18.6 percent. Yet, while this third alternative fails to reduce the poverty rate as much as the second alternative does, it allows for less pronounced inequalities between households in poverty, in the sense that the poverty gap (defined as the aggregate difference between the income of households living in poverty and the poverty line: percentage of the latter divided by the total number of households) (Foster et al. 1984), is lower in this case. When using an inequality measurement such as the Gini index[34], the second and third transfer schemes are those with a bigger impact on inequality as they involve a reduction of the index by 2.4 percent (compared with a 0.8 percent reduction of the index in the first scheme).

The extra-revenue obtained from the second reform would allow the government to transfer 389 pesos (29.26 US$) to every household in the first recycling scheme; 1,763 (132.7 US$) in the second case and between 1,129 and 11,750 pesos (84.9-884 US$) in the third one. With respect to the preceding reform, this alternative shows a similar qualitative impact on poverty, albeit less intensive due to the lower amount transferred to each household. The effects of this reform on the Gini index are obviously smaller as well, with a 0.2 percent reduction in the case of the first transfer scheme and a 0.6 percent reduction in the other two schemes. In any case, although the effects of this reform on poverty indicators are limited, it may be an interesting

[34] Table C8 in Appendix C provides full information on all the Gini results.

alternative when considering the substantial payment increases with respect to the other reforms.

When devoting the resources generated by the third reform to the contemplated recycling options, every household in the first alternative would receive 1,182 pesos (89 US$); every household in poverty would receive 5,360 pesos (403.3 US$) in the second transfer scheme; and between 3,432 and 35,717 pesos (258.2-2,687 US$) would go to households in poverty in the third recycling alternative. The impact on poverty would be akin to those of the first reform, although slightly lower given the somewhat lower amount of the transfer. In this case the Gini index would show a 0.6 percent reduction with the first transfer scheme and a 1.7 percent reduction with the remaining schemes.

Table C4 in Appendix C provides information of the impact of the considered reforms on poverty rates by regions and areas of residence. Due to the higher level of poverty in the southern region and in rural areas, the impact of fiscal reforms on poverty rate is generally higher in the northern and central regions and in urban areas than in the southern region and in rural areas. However, the impact in absolute terms is greater in the latter.

Concerning energy poverty (see Table 4 and Tables C5-C6 in Appendix C), we see that reforms have little impact on the percentage of households in poverty. The energy poverty rate (MIS), which was initially 32.6 percent, only slightly increased in the three reforms (respectively 32.7 percent, 32.7 percent and 32.8 percent) in the absence of transfers. However, the recycling of revenues through transfers to households does allow for reduced energy poverty, especially when using equal transfers to all households in poverty. Table C6 in Appendix C shows the impact of the considered reforms on energy poverty rates by region and area of residence. Summing up, the cash-transfers of the additional revenue have a greater impact on the poorer regions and areas, both in absolute and relative terms.

Table 4. Poverty, energy poverty (MIS), and food poverty rates for the reforms (percent)

		Transfer scheme 1	Transfer scheme 2	Transfer scheme 3
Poverty *(baseline: 22.1)*	**Reform 1**	21.76	17.26	18.58
	Reform 2	21.99	20.84	21.36
	Reform 3	21.90	18.60	19.73
Energy Poverty *(baseline: 32.6)*	**Reform 1**	31.56	30.65	30.96
	Reform 2	32.39	32.26	32.39
	Reform 3	32.13	31.48	31.73
Food Poverty *(baseline: 11.09)*	**Reform 1**	9.82	6.26	8.05
	Reform 2	10.73	10.34	10.36
	Reform 3	10.24	9.04	8.81

Finally, we analyze the impacts on food poverty of recycling the additional revenue raised with the reforms under the three schemes, and the results are also positive. In this sense, once transfers are given to households with each reform and recycling alternative, we again compare the equivalent basket of goods to the new disposable household income and calculate the average food poverty rates (depicted by Table 4). We find Reform 1 as the most positive in terms of food poverty reduction under each of the transfer schemes. Regarding transfer schemes, none can be defined as superior in terms of food poverty rates; it all depends on the reform. Remarkably, reform 1 coupled with the second transfer scheme helps reduce the average food poverty rate by more than 43.5 percent. The impact of the reforms on the food poverty rate is generally higher in rural areas and larger (smaller) in the poorest southern region with the third (first) transfer scheme (lower with the first scheme). The impact of the second redistributive scheme on food poverty depends on the reform (see Table C7 in Appendix C).

IV. Conclusions

In this paper we estimate a household demand system to analyze the socioeconomic impact of different energy reforms and redistributive packages in Mexico. Two of these reforms (1 and 2) have actually been implemented by the Mexican government in the last few months, although we provide various revenue recycling alternatives that might be introduced with equity purposes to compensate potential regressive effects or alleviate poverty. Although yet to be implemented, the third reform may be a reality in the next few years given the ongoing reforms in the Mexican electricity domain. Our results constitute the first comprehensive ex-ante micro assessment of the aforementioned reforms and show that they have a significant potential to reduce household energy demand and associated greenhouse gas (and local) emissions, as well as poverty (including energy and food poverty), by recycling their revenues in certain ways.

The estimation of the demand system reveals significant differences between price and income elasticities of households with vehicles and those without vehicles in Mexico. Food, LPG and gasoline are luxury goods for both types of households but electricity is a normal good for households owning vehicles while it is a luxury good for non-owning households, more sensitive to income level changes. In terms of price elasticities, electricity is an elastic good while food, LPG, gasoline and other goods are inelastic, and households with vehicles are more sensitive to price changes in all goods. Geographic location and the level of income and prices, household equipment, composition and educational level of the household are among the variables affecting Mexican household energy demand.

Simulations are carried out with the parameter estimates provided by the demand system and analyze the impact of three reforms: the introduction in 2014 of gasoline taxes (IEPS) established in 2016, the suppression of the 2014 gasoline subsidy (IEPS) and the partial elimination of electricity subsidies. Moreover, the additional revenue generated in each of the preceding reforms is devoted to make transfers to households so that poverty levels are reduced. The results of the simulations show that the reforms would generate additional 710-3,045 million US$ (0.05-0.23 percent of Mexican GDP in 2014) that would have a progressive impact on income, especially in the case of the first and third reforms. In addition, they would reduce Mexican household energy demand (electricity, LPG and gasoline) between 12.7 percent and 26 percent, and they would mitigate CO_2 emissions between 5.7 percent and 12.7 percent. Furthermore, transfers to households would reduce the poverty and energy poverty rates, especially in the case of a lump-sum transfer to all households in poverty. However, a transfer inversely proportional to the income level of households in poverty would be the best alternative to reduce the poverty gap. Finally, recycling additional revenues would also reduce the levels of food poverty, especially in the case of the first reform.

For many years Mexico has had high (explicit and implicit) energy subsidies that are unsustainable from economic, distributional and environmental angles. The recent Mexican energy reform constitutes an ambitious attempt to deal with this matter. However, international experience shows that putting energy prices 'right' requires long-term plans and the introduction of mechanisms that can accommodate the transition (IMF 2013). This paper shows the various socio-economic and environmental benefits of increased taxation and subsidy removal of energy goods in Mexico. It also provides detailed ex-ante evidence on the effects of compensatory devices that may contribute to a successful implementation of energy reform packages and to significant poverty alleviation in Mexico.

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Appendix A
Mexican Energy Data

The ENIGH survey, provided by the Mexican National Institute of Statistics and Geography, is carried out every two years. The survey uses direct interviews to collect household budget data from a representative sample of Mexican households with the use of stratified random sampling. The survey collects information on the value of household expenses in different goods during the first three months of the year, and provides detailed information on demographic and dwelling characteristics[35]. Table A1 depicts the summary statistics for the ENIGH variables used in our model while Figure A1 shows the evolution of spending shares, prices and total expenditures throughout the sample period (1994-2014).

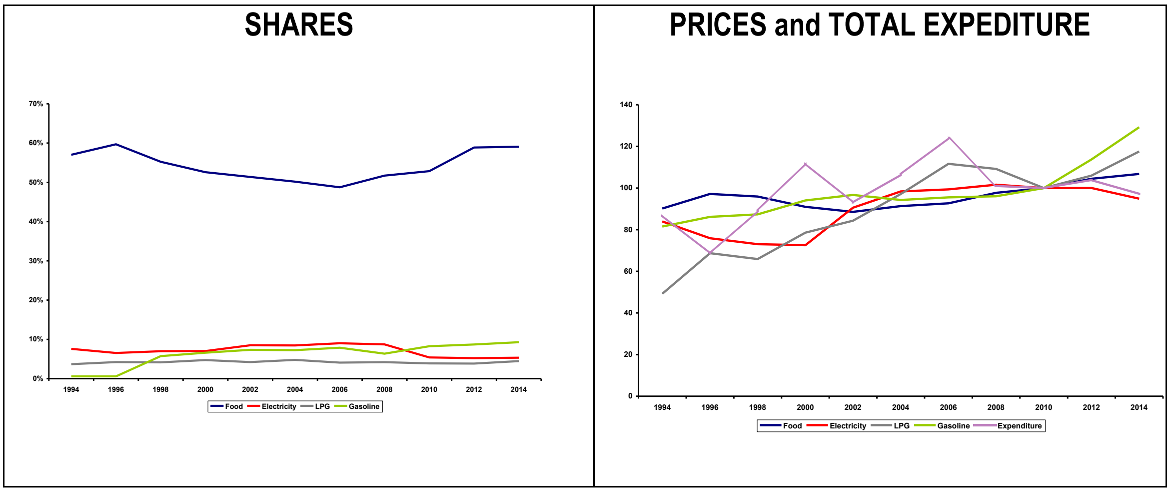
Table A1. Summary statistics for the energy demand model variables

Variable	Observations	Mean	Std. Dev.	Min	Max
Food share	119406	0.5474	0.1704	0.0047	0.9835
Electricity share	119406	0.0706	0.0649	0.0002	0.8701
LPG share	119406	0.0401	0.0493	0	0.6748
Gasoline share	119406	0.0650	0.1107	0	0.8462
Other ND share	119406	0.2769	0.1401	0.0010	0.9711
Ln (food price)	119406	-0.0407	0.0655	-0.2278	0.1300
Ln (electricity price)	119406	-0.1570	0.1446	-0.5573	0.0673
Ln (LPG price)	119406	-0.0488	0.2323	-1.0382	0.4522
Ln (gasoline price)	119406	-0.0292	0.1263	-0.6645	0.2853
Ln (other ND price)	119406	-0.0042	0.0135	-0.0798	0.0367
Ln (Expenditure)	119406	8.9432	0.7209	6.6766	10.4768
Gender	119406	0.7692	0.4214	0	1
Age	119406	47.4078	15.8571	0	97

[35] See http://www.inegi.org.mx for a comprehensive description of the survey and sampling methods.

Members ≥12 years	119406	3.1055	1.5181	1	17
Members < 12 years	119406	1.0024	1.1961	0	11
Urban	119406	0.7616	0.4261	0	1
North	119406	0.2641	0.4408	0	1
Center	119406	0.4692	0.4991	0	1
Primary school	119406	0.6454	0.4784	0	1
High school	119406	0.1122	0.3156	0	1
University	119406	0.1300	0.3363	0	1
Car	119406	0.2527	0.4346	0	1
Van	119406	0.1388	0.3457	0	1
Radio	119406	0.2505	0.4333	0	1
Radio-tape recorder	119406	0.3462	0.4758	0	1
TV	119406	0.6872	0.4636	0	1
Videotape player	119406	0.2266	0.4186	0	1
Blender	119406	0.8429	0.3639	0	1
Microwave	119406	0.3495	0.4768	0	1
Refrigerator	119406	0.8095	0.3927	0	1
Stove	119406	0.8919	0.3105	0	1
Washing machine	119406	0.6020	0.4895	0	1
Iron	119406	0.8549	0.3522	0	1
Fan	119406	0.5412	0.4983	0	1
Vacuum cleaner	119406	0.0711	0.2569	0	1
Computer	119406	0.1908	0.3929	0	1

Figure A1. Evolution of the spending shares (percent), prices and total per capita expense in Mexico 1994-2014 (2010=100)



Source: Our own calculations, based on ENIGH and INEGI data

Appendix B
Details of the econometric model

The QUAIDS assumes the following cost function:

(B1) $$\ln c(u,p) = \ln a(p) + \frac{ub(p)}{1-\lambda(p)b(p)u}$$

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

(B2) $$\ln V = \left\{ \left[\frac{\ln m - \ln a(p)}{b(p)} \right]^{-1} + \lambda(p) \right\}^{-1}$$

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

(B3) $$\ln a(p) = \alpha_0 + \sum_{i=1}^{n} \alpha_i \ln p_i + \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \gamma_{ij} \ln p_i \ln p_j \qquad b(p) = \prod_{i=1}^{n} p_i^{\beta i}$$

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 of prices, and defined as $\lambda(p) = \sum_{i}^{n} \lambda_i \ln p_i$

Applying Shephard's lemma to the cost function (B1) or Roy's identity to the indirect utility function (B2), the share equation for good i is expressed as:

(B4) $$w_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln p_j + \beta_i \ln\left[\frac{m}{a(p)}\right] + \frac{\lambda_i}{b(p)} \left\{ \ln\left[\frac{m}{a(p)}\right] \right\}^2$$

where w_i is the budget share of the non-durable good i (i = 1, … K) and α, γ, β, and λ are parameters to be estimated. In this piece of research, the intercept α_i incorporates a wide range of household and individual demographic characteristics, thus $\alpha_i = \alpha_i(z_{ht})$. We also introduce heterogeneity in the demand responses to variation in total expenditure, $\beta_i = \beta_i(z_{ht})$. Additionally, the demand should satisfy additivity of budget shares, homogeneity of price responses and Slutsky symmetry:

Adding up: (B5) $\sum_{i=1}^{n}\alpha_i = 1, \sum_{i=1}^{n}\beta_i = 0, \sum_{j=1}^{n}\gamma_{ij} = 0, \sum_{i=1}^{n}\lambda_i = 0,$

Homogeneity : (B6) $\sum_{j=1}^{n}\gamma_{ij} = 0,$

Symmetry: (B7) $\gamma_{ij} = \gamma_{ji}$

Considering that households take decisions at the extensive margin previous to demand choices, a model for good *i* can be expressed as,

(B8) $$d_i^* = z_i^{'}\gamma_i + \upsilon_i$$

(B9) $$w_i^* = f\left(x_i^{'}\beta_i\right) + \varepsilon_i$$

(B10) $$d_i = \begin{cases} 1 & if\ d_i^* \succ 0 \\ 0 & if\ d_i^* \le 0 \end{cases}$$

(B11) $$w_i = d_i w_i^*$$

where **x** and **z** are vectors of sets of explanatory variables, d_i and w_i are two dependent variables for the consumption decision and budget share of good *i*, respectively, and d_i^* and w_i^* their corresponding unobserved latent variables. The process is implemented through the estimation of a probit model in the first stage and the calculation of the Inverse Mills Ratio (IMR) that, in turn, is used to correct the budget share equations of all goods at the second stage. Given that, to simulate the proposed reforms, we need not only the estimated parameters for vehicle owners but for the whole population, we also estimate the equations for non-owners of vehicles (i.e., a kind of Roy model as described, for instance by Cameron and Trivedi 2005).

We derive the price and total expenditure elasticities (taking into account the whole model), which adopt the following expressions, (B12) $$\mu_i = \frac{\partial w_i}{\partial \ln m} = \beta_i + \frac{2\lambda_i}{b(p)}\left\{\ln\left[\frac{m}{a(p)}\right]\right\}$$

$$\mu_{ij} = \frac{\partial w_i}{\partial \ln p_j} = \lambda_{ij} - \mu_i\left(\alpha_j + \sum_k \gamma_{jk} \ln P_k\right) - \frac{\lambda_i \beta_j}{b(p)}\left\{\ln\left[\frac{m}{a(p)}\right]\right\}^2$$

The budget elasticities are given by $e_i = \frac{\Phi(z_i^{'}\gamma_i)\mu_i}{w_i} + 1$, where $\Phi(\ )$ is the standard normal cumulative distribution. The uncompensated price elasticities are given by $e_{ij}^{u} = \frac{\Phi(z_i^{'}\gamma_i)\mu_{ij}}{w_i} + \phi * \tau_{ij} * \left(1 - \frac{\delta_i}{w_i}\right) - \delta_{ij}$,, where δ_{ij} is the Kronecker delta, τ_{ij} is the estimated parameter for price *j* with respect to good item *i* in the probit model. We use the Slutsky equation, $e_{ij}^{c} = e_{ij}^{u} + e_i w_j$, to calculate the set of compensated e_{ij}^{c} and assess the symmetry and negativity conditions by examining the matrix with elements that should be symmetric and negative semi definite in the usual way. To derive an expression of the variance estimator required for confidence intervals, we use the delta method.

Appendix C

Estimation and simulation results

Table C1. Estimates of the QUAIDS model for household demand conditional on owning a vehicle

Variable	Food	Electricity	LPG	Gasoline	Other non-durables
Intercept	-1.0334	0.6466	-0.3078	-0.3126	2.0072
	(-8.23)	(11.55)	(-7.98)	(-2.92)	(18.38)
Ln (food price)	-0.2696	0.2221	-0.1237	-0.1092	0.2804
	(-4.71)	(9.73)	(-10.75)	(-4.30)	(5.86)
Ln (electricity price)	0.2221	-0.1749	0.0822	0.0227	-0.1521
	(8.52)	(-11.12)	(11.66)	(1.31)	(-7.53)
Ln (LPG price)	-0.1237	0.0822	-0.0241	-0.0531	0.1187
	(-7.03)	(9.26)	(-3.60)	(-3.75)	(6.70)
Ln (gasoline price)	-0.1092	0.0227	-0.0531	-0.0402	0.1798
	(-4.21)	(1.29)	(-5.40)	(-1.34)	(4.48)
Ln (other ND price)	0.2804	-0.1521	0.1187	0.1798	-0.4268
	(4.85)	(-7.04)	(7.66)	(4.38)	(-6.67)
Ln (Expenditure)	0.3516	-0.1808	0.0875	0.0551	-0.3134
	(13.61)	(-15.51)	(10.62)	(2.57)	(-14.02)
Ln(Expenditure)^2	-0.0253	0.0123	-0.0063	0.0075	0.0118
	(-14.92)	(15.75)	(-11.56)	(5.65)	(8.24)
Gender	0.0457	-0.0045	0.0017	0.0105	-0.0534
	(13.58)	(-2.98)	(1.72)	(3.57)	(-18.05)
Age	0.0054	0.0010	0.0005	-0.0016	-0.0054
	(12.47)	(5.01)	(4.26)	(-4.10)	(-13.86)
Age^2	-0.0001	0.0000	0.0000	0.0000	0.0000
	(-11.99)	(-2.18)	(-1.44)	(3.28)	(11.78)
Members ≥12 years	-0.0104	-0.0060	-0.0065	-0.0086	0,0314
	(-1.53)	(-1.97)	(-3.28)	(-1.45)	(5.23)
Members < 12 years	0.0155	0.0008	-0.0012	-0.0198	0.0046
	(12.46)	(1.53)	(-3.22)	(-18.55)	(4.29)
Urban	0.0584	-0.0075	0.0238	-0.0310	-0.0437
	(2.35)	(-0.67)	(3.30)	(-1.42)	(-1.99)
North	0.2299	-0.1228	0.0430	0.0991	-0.2492
	(4.43)	(-9.79)	(5.25)	(4.15)	(-10.32)
Center	0.0109	-0.0095	0.0092	0.0071	-0.0176
	(4.43)	(-8.66)	(12.82)	(3.29)	(-8.12)
Primary school	0.0338	0.0028	0.0034	-0.0069	-0.0331
	(7.54)	(1.42)	(2.56)	(-1.76)	(-8.31)
High school	0.0394	0.0058	0.0043	0.0024	-0.0518
	(7.00)	(2.29)	(2.59)	(0.48)	(-10.40)
University	0.2105	-0.0512	0.0048	0.0767	-0.2408

	(6.11)	(-3.33)	(0.48)	(2.56)	(-7.95)
Car	-0.0295	0.0035	-0.0012	0.0367	-0.0095
	(-12.33)	(3.25)	(-1.66)	(17.44)	(-4.47)
Van	-0.0359	0.0009	-0.0007	0.0435	-0.0079
	(-14.96)	(0.88)	(-0.94)	(20.72)	-3.72
Radio	0.0026	0.0001	0.0026	-0.0006	-0.0047
	(1.56)	(0.12)	(5.48)	(-0.40)	(-3.22)
Radio-tape recorder	0.0039	-0.0019	0.0001	-0.0067	0.0046
	(2.52)	(-2.71)	(0.31)	(-4.98)	(3.35)
TV	0.0270	-0.0187	-0.0006	-0.0118	0.0041
	(11.51)	(-17.90)	(-0.93)	(-5.78)	(1.97)
Videotape player	0.0018	-0.0009	0.0028	-0.0079	0.0043
	(1.04)	(-1.24)	(5.72)	(-5.36)	(2.87)
Blender	0.0103	0.0014	0.0040	-0.0116	-0.0041
	(3.23)	(0.95)	(4.32)	(-4.12)	(-1.44)
Microwave	-0.0106	0.0086	0.0006	-0.0023	0.0037
	(-5.77)	(10.52)	(1.13)	(-1.46)	(2.28)
Refrigerator	-0.0073	0.0104	0.0005	-0.0184	0.0148
	(-1.82)	(5.76)	(0.43)	(-5.19)	(4.12)
Stove	-0.0049	0.0064	0.0182	-0.0272	0.0075
	(-1.01)	(2.96)	(12.90)	(-6.39)	(1.73)
Washing machine	0.0090	0.0037	0.0001	-0.0174	0.0046
	(3.85)	(3.55)	(0.10)	(-8.51)	(2.23)
Iron	0.0049	0.0001	0.0012	-0.0150	0.0088
	(1.54)	(0.05)	(1.28)	(-5.27)	(3.04)
Fan	0.00048	0.0066	-0.0079	-0.0069	0.0033
	(2.94)	(9.06)	(-16.49)	(-4.76)	(2.24)
Vacuum cleaner	-0.0051	0.0046	0.0014	-0.0027	0.0018
	(-2.40)	(4.91)	(2.20)	(-1.47)	(0.97)
Computer	-0.0079	0.0056	-0.0014	-0.0082	0.0119
	(-3.48)	(5.53)	(-2.06)	(-4.20)	(5.97)
Members ≥12 years *Ln (Expenditure)	0.0017	0.0007	0.0005	-0.0017	-0.0013
	(2.54)	(2.32)	(2.73)	(-2.84)	(-2.17)
Urban *Ln (Expenditure)	-0.0053	0.0014	-0.0028	0.0008	0.0059
	(-2.16)	(1.31)	(-3.96)	(0.38)	(2.69)
North *Ln (Expenditure)	-0.0246	0.0140	-0.0030	-0.0052	0.0188
	(-10.12)	(12.90)	(-4.24)	(-2.49)	(8.92)
University *Ln (Expenditure)	-0.0164	0.0055	0.0001	-0.0056	0.0164
	(-5.46)	(4.08)	(0.12)	(-2.13)	(6.19)
IV (ND expenditure)	0.0430	-0.0021	-0.0191	-0.1851	0.1633
	(2.41)	(-0.26)	(-3.65)	(-12.28)	(10.61)
Heckman's lambda	0.0997	-0.0022	0.0078	0.0297	0.1350
	(9.83)	(-0.49)	(2.61)	(3.40)	(-15.31)

Table C2. Estimates of the QUAIDS model for household demand conditional on not owning a vehicle

Variable	Food	Elec	LPG	Other non-durables
Intercept	-0.7116	0.2576	-0.1810	1.6350
	(-10.60)	(9.86)	(-8.02)	(24.71)
Ln (food price)	0.1032	0.0061	-0.0708	-0.0384
	(4.09)	(0.82)	(-13.00)	(-1.67)
Ln (electricity price)	0.0061	-0.0373	0.0288	0.0024
	(0.66)	(-9.73)	(11.61)	(0.31)
Ln (LPG price)	-0.0708	0.0288	-0.0038	0.0458
	(-6.20)	(6.36)	(-0.90)	(3.82)
Ln (other ND price)	-0.0384	0.0024	0.0458	-0.0098
	(-1.47)	(0.35)	(7.69)	(-0.39)
Ln (Expenditure)	0.2931	-0.0949	0.0512	-0.2494
	(21.46)	(-18.21)	(10.93)	(-18.62)
$Ln(Expenditure)^2$	-0.0184	0.0089	-0.0041	0.0135
	(17.03)	(22.44)	(-11.05)	(13.04)
Gender	0.0717	0.0020	0.0038	-0.0775
	(21.41)	(1.57)	(3.41)	(-23.71)
Age	0.0065	0.0008	0.0004	-0.0078
	(17.54)	(5.85)	(3.30)	(21.47)
Age^2	-0.0001	0.0000	0.0000	0.0001
	(16.65)	(-2.60)	(0.12)	(18.09)
Members ≥12 years	-0.0230	-0.0034	-0.0077	0.0342
	(-5.49)	(-2.07)	(-5.56)	(8.40)
Members < 12 years	0.0083	-0.0013	-0.0012	-0.0057
	(11.13)	(-4.64)	(-4.80)	(-7.94)
Urban	-0.0240	0.0390	0.009	-0.0190
	(-1.54)	(6.41)	(0.76)	(-1.25)
North	0.1552	-0.0082	0.0366	-0.1836
	(8.92)	(-1.21)	(6.34)	(-10.86)
Center	0.0240	0.0046	0.0124	-0.0410
	(13.11)	(6.46)	(20.39)	(-23.03)
Primary school	0.0295	0.0045	0.0063	-0.0403
	(11.02)	(4.28)	(7.12)	(-15.45)
High school	0.0399	0.0066	0.0084	-0.0549
	(8.89)	(3.75)	(5.64)	(-12.54)
University	0.0382	0.0182	-0.0027	-0.0538
	(1.14)	(1.39)	(-0.24)	(-1.65)
Radio	-0.0024	0.0016	0.0006	0.0002
	(-1.81)	(3.14)	(1.28)	(0.17)
Radio-tape recorder	-0.0023	-0.0019	-0.0006	0.0048
	(-1.84)	(-3.91)	(-1.52)	(3.98)
TV	0.0060	-0.0086	0.0007	0.0019
	(3.71)	(-13.51)	(1.26)	(1.18)

Videotape player	-0.0051	-0.0003	0.0004	0.0050
	(-3.14)	(-0.54)	(0.83)	(3.16)
Blender	0.0004	-0.0013	0.0036	-0.0026
	(0.22)	(-1.95)	(6.28)	(-1.58)
Microwave	-0.0070	0.0024	0.0013	0.0033
	(-4.34)	(3.83)	(2.36)	(2.12)
Refrigerator	-0.0177	0.0136	-0.0002	0.0042
	(-9.63)	(19.03)	(-0.25)	(2.35)
Stove	-0.0443	0.0021	0.0336	0.0085
	(-19.62)	(2.43)	(44.86)	(3.88)
Washing machine	0.0040	0.0007	0.0004	-0.0051
	(2.78)	(1.33)	(0.87)	(-3.69)
Iron	-0.0074	-0.0025	0.0024	0.0075
	(-4.37)	(-3.77)	(4.31)	(4.53)
Fan	-0.0040	0.0074	-0.0065	0.0031
	(-3.13)	(14.95)	(-15.45)	(2.49)
Vacuum cleaner	-0.0080	0.0073	-0.0008	0.0014
	(-1.85)	(4.38)	(-0.53)	(0.33)
Computer	-0.0050	-0.0006	0.0004	0.0052
	(-2.13)	(-0.68)	(0.53)	(2.28)
Members ≥12 years *Ln (Expenditure)	0.0018	0.0001	0.0006	-0.0025
	(4.10)	(0.37)	(4.17)	(-5.80)
Urban *Ln (Expenditure)	0.0005	-0.0040	-0.0005	0.0040
	(0.30)	(6.19)	(-0.89)	(2.48)
North *Ln (Expenditure)	-0.0135	0.0051	-0.0021	0.0105
	(7.80)	(7.54)	(-3.68)	(6.26)
University *Ln (Expenditure)	-0.0001	-0.0009	0.0012	-0.0001
	(-0.02)	(-0.73)	(1.05)	(-0.04)
IV (ND expenditure)	-0.0282	-0.0476	-0.0143	0.0902
	(-2.65)	(-11.52)	(4.04)	(8.63)
Heckman's lambda	-0.1322	-0.0149	-0.0121	0.1592
	(16.46)	(-4.75)	(-4.52)	(20.28)

Table C3. Estimates of the QUAIDS model for household demand. Unconditional to vehicle ownership

Variable	Food	Elec	LPG	Gasoline	Other non-durables
Intercept	0.2294	0.3908	-0.2281	-0.2028	0.8108
	(5.46)	(23.59)	(16.84)	(-9.70)	(21.48)
Ln (food price)	0.1423	-0.0257	-0.0187	0.0689	-0.1668
	(12.21)	(-4.38)	(-4.03)	(10.31)	(-15.68)
Ln (electricity price)	-0.0257	-0.0742	0.0542	0.0007	0.0449
	(-3.52)	(-18.13)	(22.41)	(0.19)	(7.22)
Ln (LPG price)	-0.0187	0.0542	-0.0218	-0.0275	0.0137
	(-2.29)	(15.52)	(-6.78)	(-6.57)	(1.80)
Ln (gasoline price)	0.0689	0.0007	-0.0275	-0.0040	-0.0381
	(8.90)	(0.18)	(-9.72)	(-0.83)	(-4.98)
Ln (other ND price)	-0.1668	0.0449	0.0137	-0.0381	0.1463
	(-17.37)	(9.34)	(3.83)	(-7.86)	(15.58)
Ln (Expenditure)	0.1002	-0.1099	0.0696	0.0526	-0.1125
	(8.99)	(-24.96)	(19.23)	(9.52)	(-11.20)
Ln(Expenditure)^2	-0.0080	0.0078	-0.0048	-0.0012	0.0062
	(-10.24)	(25.06)	(-19.01)	(-3.01)	(8.82)
Gender	0.0186	-0.0038	-0.0010	0.0040	-0.0178
	(16.73)	(-8.65)	(-2.91)	(7.29)	(-17.98)
Age	0.0019	0.0006	-0.0000	-0.0004	-0.0021
	(8.48)	(6.88)	(-0.41)	(-3.69)	(-10.36)
Age^2	-0.0000	-0.0000	0.0000	0.0000	0.0000
	(-7.23)	(-1.66)	(6.02)	(3.06)	(5.01)
Members ≥12 years	0.0352	-0.0087	0.0009	0.0226	-0.0500
	(8.99)	(-5.59)	(0.76)	(11.58)	(-14.36)
Members < 12 years	0.0149	0.0001	-0.0014	-0.0049	-0.0087
	(28.78)	(0.35)	(-8.52)	(-18.84)	(-18.88)
Urban	0.2180	0.0228	0.0582	-0.0183	-0.2807
	(15.62)	(4.12)	(13.23)	(-2.63)	(-22.59)
North	0.1314	-0.0611	0.0333	-0.0598	-0.0438
	(11.30)	(-13.22)	(9.08)	(-10.32)	(-4.23)
Center	0.0026	-0.0012	0.0091	0.0009	-0.0114
	(2.10)	(-2.48)	(23.35)	(1.42)	(-10.31)
Primary school	-0.0050	0.0016	0.0022	-0.0038	0.0051
	(-3.02)	(2.41)	(4.16)	(-4.62)	(3.43)
High school	-0.0207	0.0024	0.0014	-0.0002	0.0171
	(-9.20)	(2.67)	(1.99)	(-0.21)	(8.55)
University	-0.0298	-0.0483	-0.0268	-0.1475	0.2524
	(-1.61)	(-6.59)	(-4.61)	(-15.99)	(15.34)
Car	-0.0540	0.0017	-0.0050	0.1322	-0.0748
	(-35.64)	(2.77)	(-10.44)	(174.5)	(-55.36)
Van	-0.0618	-0.0019	-0.0042	0.1235	-0.0555
	(-35.60)	(-2.77)	(-7.71)	(142.18)	(-35.85)

Radio	0.0000 (-0.01)	0.0011 (2.52)	0.0017 (5.12)	-0.0010 (-1.93)	-0.0017 (-1.85)
Radio-tape recorder	0.0003 (0.28)	-0.0021 (-5.45)	0.0001 (0.29)	-0.0023 (-4.64)	0.0040 (4.61)
TV	0.0181 (13.29)	-0.0121 (-22.35)	-0.0011 (-2.55)	-0.0080 (-11.71)	0.0030 (2.49)
Videotape player	-0.0003 (-0.25)	0.0006 (1.25)	0.0016 (4.33)	-0.0061 (-10.23)	0.0042 (3.93)
Blender	0.0028 (1.85)	0.0010 (1.70)	0.0027 (5.56)	-0.0021 (-2.78)	-0.0044 (-3.25)
Microwave	-0.0081 (-6.72)	0.0051 (10.77)	0.0004 (0.98)	0.0028 (4.69)	-0.0002 (-0.23)
Refrigerator	-0.0130 (-7.70)	0.0152 (22.72)	-0.0018 (-3.44)	-0.0049 (-5.82)	0.0045 (2.99)
Stove	-0.0400 (-19.46)	0.0056 (6.90)	0.0297 (45.79)	-0.0042 (-4.05)	0.0088 (4.80)
Washing machine	0.0063 (5.15)	0.0020 (4.15)	-0.0007 (-1.90)	-0.0029 (-4.77)	-0.0047 (-4.28)
Iron	-0.0074 (-4.81)	-0.0015 (-2.52)	0.0013 (2.67)	-0.0007 (-0.96)	0.0084 (6.11)
Fan	-0.0023 (-2.27)	0.0074 (18.27)	-0.0073 (-22.51)	-0.0013 (-2.45)	0.0034 (3.75)
Vacuum cleaner	-0.0043 (-2.28)	0.0059 (7.78)	0.0012 (1.98)	0.0009 (0.91)	-0.0036 (-2.11)
Computer	-0.0036 (-2.48)	0.0026 (4.51)	-0.0005 (-1.14)	0.0030 (4.07)	-0.0014 (-1.10)
Members ≥12 years *Ln (Expenditure)	-0.0031 (-6.94)	0.0009 (4.91)	-0.0003 (-2.19)	-0.0031 (-14.01)	0.0056 (14.22)
Urban *Ln (Expenditure)	-0.0226 (-14.78)	-0.0018 (-2.97)	-0.0063 (-13.11)	0.0012 (1.52)	0.0296 (21.71)
North *Ln (Expenditure)	-0.0190 (-16.25)	0.0091 (19.62)	-0.0023 (-6.22)	0.0077 (13.10)	0.0046 (4.36)
University *Ln (Expenditure)	-0.0012 (-0.67)	0.0050 (7.13)	0.0027 (4.86)	0.0155 (17.41)	-0.0221 (-13.91)
IV (ND expenditure)	0.0474 (6.71)	-0.0164 (-5.88)	-0.0235 (-10.51)	-0.0472 (-13.38)	0.0397 (6.29)

Table C4. Poverty rate by regions for the different reforms under study (%)

	Initial	R1. T1	R1. T2	R1. T3	R2. T1	R2. T2	R2. T3	R3. T1	R3. T2	R3. T3
North	15.62	15.27	11.57	12.73	15.50	14.50	15.03	15.34	12.75	13.54
Center	19.33	19.16	14.70	15.93	19.32	18.21	18.71	19.32	15.91	17.00
South	35.66	35.13	29.63	31.37	35.51	34.12	34.71	35.32	31.48	33.07
Urban	15.62	15.41	11.40	12.56	15.55	14.55	15.04	15.49	12.56	13.54
Rural	45.41	44.83	38.52	40.47	45.36	43.77	44.35	45.17	40.53	42.20

Table C5. Households in energy poverty under the different reforms (%). 10% and AFCP

	10%	AFCP
Initial	***25.82***	***22.45***
Reform 1	26.56	22.32
Reform 1. T1	25.76	21.89
Reform 1. T2	25.42	18.53
Reform 1. T3	25.48	19.55
Reform 2	28.55	22.31
Reform 2. T1	27.02	22.23
Reform 2. T2	27.01	21.59
Reform 2. T3	26.95	21.77
Reform 3	23.50	22.36
Reform 3. T1	22.84	22.04
Reform 3. T2	22.77	19.94
Reform 3. T3	22.78	20.59

Table C6. Energy poverty rate by regions for the different reforms (%). MIS

	R1	R2	R3	R1. T1	R1. T2	R1. T3	R2. T1	R2. T2	R2. T3	R3. T1	R3. T2	R3. T3
North	29.68	29.78	29.58	28.32	28.48	28.75	29.43	29.47	29.50	28.77	28.74	28.99
Center	31.06	31.10	31.32	30.15	29.39	29.70	30.76	30.73	30.88	30.70	30.17	30.42
South	39.89	39.76	39.98	38.53	35.17	36.39	39.38	38.96	39.15	39.25	37.60	37.88
Urban	30.74	30.77	30.88	29.75	30.12	30.25	30.51	30.62	30.66	30.34	30.47	30.66
Rural	39.79	39.76	39.87	38.16	32.60	33.55	39.22	38.23	38.65	38.62	35.12	35.62

Table C7. Food poverty rate by region for the different reforms under study (%)

	Initial	R1. T1	R1. T2	R1. T3	R2. T1	R2. T2	R2. T3	R3. T1	R3. T2	R3. T3
North	6.55	5.66	3.32	5.17	6.29	6.21	6.22	5.88	5.58	5.56
Center	8.80	7.78	4.74	6.69	8.53	8.24	8.20	8.08	7.23	7.08
South	21.56	19.29	13.10	14.44	20.88	19.91	20.04	20.15	17.15	16.49
Urban	8.31	7.45	4.70	6.86	8.08	7.90	7.93	7.66	7.20	7.22
Rural	21.19	18.43	11.92	12.36	20.36	19.22	19.18	19.58	15.73	14.58

Table C8. Gini index under the different reforms

Initial	Reform 1			Reform 2			Reform 3		
	Transfer 1	Transfer 2	Transfer 3	Transfer 1	Transfer 2	Transfer 3	Transfer 1	Transfer 2	Transfer 3
0.438	0.434	0.427	0.427	0.437	0.435	0.435	0.435	0.430	0.430