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Petrol consumption and redistributive effects of its taxation in Spain

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Abstract. The objective of this paper is to estimate a petrol consumption function for Spain and to evaluate the redistributive effects of petrol taxation. We use micro data from the Spanish Household Budget Survey of 1990/91 and model petrol consumption taking into account the effect that income changes may have on car ownership levels, as well as the differences that exist between expenditure and consumption. Our results show the importance that household structure, place of residence and income have on petrol consumption. We are able to compute income elasticities of petrol expenditure, both conditional and unconditional on the level of car ownership. Non-conditional elasticities, while always very close to unit values, are lower for higher income households and for those living in rural areas or small cities. When car ownership levels are taken into account, conditional elasticities are obtained that are around one half the value of the non- conditional ones, being fairly stable across income categories and city sizes. As regards the redistributive effects of petrol taxation, we observe that for the lowest income deciles the share of petrol expenditure increases with income, and thus the tax can be regarded as progressive. However, after a certain income level the tax proves to be regressive.

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1. INTRODUCTION

The changes in the prices of petrol that have taken place during the last three decades have generated a growing interest in the determinants of petrol consumption. Those analyses have focused both on the effectiveness of fiscal measures as instruments for reducing demand and on obtaining reliable predictions about the impact that income growth may have on future transport demand. The attention paid to the estimation of price and income elasticities has not been matched by the interest in the redistributive effects of petrol taxation. The latter is, nevertheless, a very relevant issue, given that in most cases the opposition to higher taxes on petrol in order to control demand relies on arguments related to the supposedly regressive character of such taxes.

In this paper we analyse the determinants of petrol expenditure in Spain, as well as the redistributive effects generated by its taxation. We use micro data from the Spanish Household Budget Survey (*Encuesta de Presupuestos Familiares*, EPF) of 1990/91[1]. The household is defined as the unit of analysis. It is important to stress the fact that we work with a cross-section sample obtained when there was no freedom of pricing in the Spanish retail market for petrol. Because of this fact, we are unable to observe variations in petrol prices faced by the different households in the sample. This makes it impossible to include a price variable in the model. Therefore, our estimation needs to be interpreted as an expenditure function, and not as a demand one.

One of the main determinants of petrol consumption is car ownership. Given that income influences both petrol consumption and car purchase decisions, the model needs to take both processes into account. Therefore, we firstly estimate a car ownership model for the households in our sample. At a second stage, and conditional on the number of cars owned, we estimate the petrol consumption equation. The use of this two-stage method

[1] Because of this, all incomes and values refer to this year. Between 1990 and 2000 the Spanish CPI has increased by 47%, while disposable per capita income has risen around 84%. Both figures should be taken into account when interpreting the results of this paper.

makes it possible to estimate income elasticities of petrol consumption that are conditional on the number of cars owned as well as non-conditional ones.

A further interest of the paper lies in the fact that we identify the different redistributive effects that petrol taxation may have in different geographical areas. If petrol consumption patterns are not homogeneous across the country, the redistributive effects of petrol taxes will also vary. However, given the small size of the subsamples for some of the cities, it is not possible to calculate those redistributive effects directly from the sample information. Using the estimated expenditure function, the petrol expenditures of a standard household in different geographical areas and for different income levels will be simulated.

The paper is structured as follows. The second section details the modelling procedure, while the third discusses the characteristics of the database. Model estimation is carried out in the fourth section. Afterwards, a more detailed discussion of the income elasticities is presented. The sixth section focuses on the calculation of redistributive effects. In the last section the main conclusions are summarised.

2. MODELLING PETROL CONSUMPTION

Household decisions about petrol consumption essentially depend on the price of petrol, household income, household structure, residential location and other socioeconomic variables. At the same time, most of these variables also influence vehicle ownership, which in turn is one of the main determinants of petrol consumption. The consumer theory underlying such transport demand studies suggests that decisions on car ownership and car use should be simultaneously estimated[2]. In this paper, petrol consumption is treated as a proxy for vehicle use. This leaves us with two interrelated decisions that should be estimated: a discrete demand model for vehicle ownership and a continuous petrol consumption function, which is conditional on the number of vehicles owned. This way of proceeding allows for changes in the vehicle stock as a response to

[2] The theoretical framework for discrete-continous models and its application to vehicle type choice and use can be found in Mannering and Winston (1985), Train (1986) and Hensher *et al.*(1990).

variations in the exogenous variables and, therefore, to include long-term adjustments in the estimated elasticities and distributional effects.

As has been previously noted, we observe a unique petrol price for different households. This forces us to treat prices as fixed in the petrol consumption function and, therefore, to interpret it as an expenditure function (Engle curve) and not as a demand function. Price effects will be captured by the constant term in the econometric estimation.

The discrete decision on vehicle ownership has been estimated with an ordered probit model. This model is based on a latent variable y^* measuring the underlying desire for car ownership that can be expressed as

$$y^* = Xb + e \qquad (1)$$

where X is a set of explanatory variables and e is a random term. What we really observe is the number of cars owned by the household. With the help of variable y^* we can express the number of cars owned, y, as

$$\begin{aligned} &y=0 \quad \text{if } y^*< 0 \\ &y=1 \quad \text{if } 0< y^*<m_1 \\ &y=2 \quad \text{if } m_1< y^*<m_2 \qquad (2) \\ &. \\ &. \\ &y=J \quad \text{if } m_{J-1}< y^* \end{aligned}$$

where the m are unknown parameters that need to be jointly estimated with b. With this specification, the probit model estimates the probability that a household has none, one, two, or J cars[3], where J≥3. Thus, we restrict the last choice (J) to owning more than two cars. Therefore,

[3] For a discussion of the characteristics of the ordered probit model, see for instance Greene (2000).

$Prob(y=0) = F(-Xb)$

$Prob(y=1)= F(m_1-Xb)- F(-Xb)$

$Prob(y=2)= F(m_2-Xb)- F(m_1-Xb)$

$Prob(y=J)=1- F(m_{J-1}-Xb)$

where F is the standard normal cumulative distribution function.

The second modelling decision refers to the petrol consumption of the household. In order to model this decision we face the following problem: due to the fact that for many households petrol is purchased with a frequency higher than once a week, which is the surveying period of the database we employ, we have households reporting no petrol expenditure even though their consumption may be positive. On the other hand, households that have bought petrol during the week they are surveyed, may report expenditure above their real consumption. In order to solve this infrequent purchase problem and obtain reliable data for petrol consumption, we use a two-stage modelling procedure.

Under the hypothesis that all cases in which households owning at least one vehicle and reporting no petrol expenditure are due to a problem of infrequent purchase, we may correct the observed expenditure variable in the following way. Let reported petrol expenditure be represented by Y petrol consumption by Y^*. If we assume that the expected values of expenditure and consumption are equal, we can write[4]:

$$E(Y_i) = E(Y_i^*)$$

The expected value of petrol expenditure can also be written as the product of the expected expenditure for households reporting positive expenditure multiplied by the probability of spending a positive amount of money:

$$E(Y_i) = E(Y_i/D_i=1) \cdot \; p(D_i=1)$$

[4] See Deaton and Irish (1984), Blundell and Meghir (1987).

where D=1 if the household buys petrol during the week of reference and D=0 if it does not.

Given the equality of expected values, it is also true that

$$E(Y_i^*) = E(Y_i/D_i=1) \cdot p(D_i=1) \qquad (3)$$

On the other hand, considering a petrol consumption function of the type

$$E(Y_i^*)= j(q) \qquad (4)$$

where q are the parameters of the consumption function, from (3) and (4) we obtain that

$$j(q) = E(Y_i/D_i=1) \cdot p(D_i=1)$$

and

$$E(Y_i/D_i=1) = j(q)/p(D_i=1)$$

Under standard hypotheses, converting expected values into observed ones requires adding a random term:

$$(Y_i/D_i=1) = j(q)/p(D_i=1) + e_i$$

so that

$$(Y_i/D_i=1) \cdot p(D_i=1) = j(q) + e_i^*, \qquad (5)$$

where $e_i^* = e_i \cdot p(D=1)$

Therefore, petrol consumption is approximated by the product of observed expenditure times the probability of observing positive expenditure. Due to potential heteroscedasticity problems of the new random term, it may be useful to estimate the covariance matrix using a robust method, such as White's.

The probability of observing positive petrol expenditure is estimated separately for households owning different number of cars with a probit model

$$P_j(D=1) = F(Z_j g)$$

for j = 1, ..., J, where j is each car ownership level, and Z are the explanatory variables of the decision of whether to spend or not. Therefore, this first stage corrects petrol expenditure for those households that declare positive values in order to approximate real consumption by a corrected measure of expenditure.

At a second stage, we estimate a petrol consumption equation for households owning one or more cars. Available empirical evidence suggests that the coefficients of the explanatory variables that affect petrol consumption of these households may vary with the degree of motorisation. We thus adopt a flexible approach whereby a general equation is initially specified in which the explanatory variables are multiplied by dummies related to the number of cars owned by the household. A simplification process based on the coefficients' significance leads to a final specification where the only variation between the types of households refers to the intercepts and income coefficients.

This result can, nevertheless, be biased, given the fact that the continuous equation is conditional on the particular outcome of the discrete choice model and it may be subject to selection bias. In order to correct for this bias we use the classical Heckman approach, modified for the ordered probit model case (see, for example, Ermisch and Wright, [1993]). Given that the coefficient of the inverse Mill's ratio is not significantly different from zero[5], the estimated coefficients of the rest of the variables remain practically invariable and the introduction of the Mills ratio can result in notorious multicolinearity

[5] The appendix contains the models that were estimated in this specification process.

probems, our final specification of the petrol consumption equation does not correct for selection bias.

To sum up, the procedure employed to estimate the impact that income has on petrol consumption and to evaluate the redistributive effects of petrol taxation is the following: We firstly estimate the probabilities of different degrees of car ownership with the ordered probit model in (1) and (2). After correcting petrol expenditure to approximate petrol consumption, we specify a consumption equation for those households with a positive number of cars. Finally, with the help of information about petrol taxation, it will be possible to assess the importance of its redistributive effects.

3. THE DATA

We employ a sample of 20,934 households included in the 1990/91 EPF[6]. Several variables collected in this survey will be used to construct our exogenous variables. The EPF provides two variables that can be used as a measure of household income: current income and total expenditure, both in annual terms. The choice among them has been the object of some debate in the literature measuring redistributive effects. The discussion refers firstly to whether taxation should be measured with respect to current or permanent income, and in the latter case, the way in which such income may be approximated. There appears to be a certain degree of consensus on the use of permanent income as a way of determining lifetime redistributive effects. Besides, when no data from different periods are available, it is common to proxy permanent income by current consumption on the assumption that current expenditure is relatively stable with respect to income changes regarded as transitory (Poterba 1991, Alperovich *et al.* 1999). Another reason for not using current income is the significant downward bias to which it may be subject because of underreporting by the surveyed households. Therefore, we interpret current expenditure as a proxy of permanent income, assuming that households maintain relatively stable consumption patterns that match their lifetime income more accurately than current income.

[6] The whole EPF sample consists of 21,155 households, but exclude those from the Spanish northafrican cities of Ceuta and Melilla given that information on some explanatory variables was not available for those cities.

The following variables will be used in the different stages of the modelling analysis:

- PETROL expenditure
- Household INCOME, proxied by current expenditure.
- Number of ADULTS
- Number of CHILDREN
- Number of EMPLOYED members of the household.
- Number of RETIRED members of the household.
- Age of the head of the household: AGE1 if younger than 25, AGE2 if between 25 and 35, AGE3 if between 35 and 55, AGE4 if between 55 and 65, and AGE5 if older than 65.
- Years of EDUCATION of the head of the household. The EPF reports education levels, which have been converted into equivalent years of studies.
- Number of CARS
- Number of MOTORCYCLES.
- Size of the municipality of residence. We define categories for each of the cities with population over half a million (in decreasing size, MADRID, BARCELONA, SEVILLA, VALENCIA, MALAGA and ZARAGOZA) and three categories containing all other municipalities: LARGE (between 100,000 and 500,000 residents), MEDIUM (between 10,000 and 100,000) and SMALL (less than 10,000).
- QUALITY of the road network. This variable is calculated as the length of the road network in each province corrected by the population and size of the province.

Table 1 summarises the main descriptive statistics of the variables, as well as the sample distribution according to size of the municipalities of residence.

Given that petrol taxation amounts to a fixed percentage of petrol consumption, its redistributive effects will depend on the relative shares of petrol consumption in different income groups. As a first approximation to the evaluation of the redistributive impact, Figure 1 shows the share of petrol in total expenditure for the population sampled in the EPF. It can be observed that the share of petrol expenditure, and thus petrol taxation, rises up to the fifth decile, subsequently falling. Petrol taxation can therefore be defined as progressive for the poorer half of the population but regressive for the richer one. However, we attempt to define those redistributive effects more precisely. With the help of the consumption model it is possible to simulate the petrol consumption for different household types and different income levels. This will enable us to approximate the redistributive effects of petrol taxation in different geographical areas. This approach circumvents the problem of absence of information for certain household categories that are not well represented in the available sample.

4. ESTIMATION RESULTS

This section shows and comments on the estimation results of the models put forward in Section 2. As already mentioned, car ownership probabilities are estimated with an ordered probit model with four categories for the dependent variable: no car, one car, two cars and more than two cars. It has to be pointed out that the interpretation of the coefficients of an ordered probit model is not direct. A coefficient cannot be identified with the regressor's marginal effect on probability. Computing the marginal effects requires an evaluation of the standard normal density function for given values of Xb. Only in the extremes of the probability function can the signs of the coefficients be directly interpreted. A positive coefficient implies a negative impact on the probability that the household has no car and a positive one on the chances that it has more than two. The impact on the intermediate categories (one or two cars) is ambiguous and depends on the corresponding values of the distribution function.

Estimation results of the car ownership model are shown in Table 2, where some equality restrictions have been imposed on the coefficients of the city of residence dummies: Madrid and Barcelona are jointly defined as the category of reference, a second variable identifies households living in Valencia, Sevilla, Malaga or Zaragoza, while the rest of the coefficients are not constrained. None of the restrictions involved in these groupings is rejected by the data. The results show that the probability that a household has no car is lower, the larger the municipality of residence. *Ceteris paribus*, the highest probability that a household owns no car is found in Madrid and Barcelona, with the lowest value corresponding to the smallest localities. This result is in accordance with *a priori* expectations, given that Madrid and Barcelona are Spain's biggest cities, have the largest public transport networks and suffer the worst congestion problems, with the lowest circulation speeds for private cars and the highest parking prices. As expected, car ownership levels rise with income, education of the head of the household and the number of adults and workers in the household. The age of the head of the household also has a significant effect on car ownership: those younger than 25 or older than 55 show lower probabilities of owning cars than those in the age of reference (35-55). Finally, car ownership probabilities are directly related to the quality of the provincial road network

Table 3 summarises car ownership probabilities in the case of a household with two adults, of whom only one is employed, total income of 15,025 euros and whose head of household has 11 years of education and is aged between 35 and 55 years. The city of residence is allowed to vary to show how it influences motorization levels.

Once car ownership probabilities are known, we turn to the problem of estimating petrol consumption. As explained above, before estimating the consumption function it is advisable to solve the problem due to the infrequent purchase of petrol. This requires estimations of the probability that the household spends a positive amount in petrol during the survey's reference week. Tables 4 and 5 show the results of such probit estimations for households with one or two cars. It is assumed that households without a car do not consume petrol, while we observe that those with more than two vehicles always have positive weekly expenditure on petrol.

Once the infrequent purchase problem has been corrected, we estimate the petrol consumption function as linear in the parameters, taking logarithms on both the dependent variable and household income. This results in a better fit. Besides income, explanatory variables include household socioeconomic variables and the municipality of residence. Given the possible presence of heteroscedasticity in the error term, the variance matrix has been robustly estimated with White's method. As explained above, the different impact of explanatory variables on petrol consumption according to the number of cars owned by the household is taken into account, allowing the interaction of car ownership dummies with those variables. In the final specification, shown in Table 6, only income variation leads to significant petrol consumption changes in households owning different numbers of cars. The income elasticity of petrol consumption is lower for households with a higher number of cars. Given the positive correlation between motorization levels and income, this result reflects, at least in part, the falling income elasticity of petrol consumption as income increases. Results in Table 6 also show that petrol consumption rates are higher for those households living in municipalities with fewer than 10,000 habitants. The age of the head of the households also has a significant influence: households with younger household heads show higher consumption rates.

5. INCOME ELASTICITIES

The estimation of the petrol consumption function allows us to calculate income elasticities. This is a relevant variable in order to predict the impact that income growth may have on future transport demand. Given that a vehicle ownership model has been specified together with a continuous consumption function, it is possible to calculate long-term (non conditional) and short-term (conditional) income elasticities. The latter only take into account the direct effect that income variation has on vehicle use and petrol consumption, thus considering the number of vehicles owned as fixed. Long-term elasticities also take into account the impact on petrol consumption via increased car ownership as a result of higher incomes, thus adding direct and indirect effects.

Income elasticities have been calculated for a standard household composed of two adults, of whom only one works, two children and no retired persons. The head of the household is assumed to be aged between 35 and 55, with 11 years of education. Elasticities have been calculated for four income levels, corresponding to the average income for each quartile, which we term high, medium-high, medium-low and low. Different values have been obtained for the following groups of cities: Madrid and Barcelona; Valencia, Sevilla, Malaga and Zaragoza; large, medium and small municipalities. Table 9 shows the results.

Long term elasticity is shown to be around unity, decreasing as income rises. Moreover, demand is more elastic in large urban areas, with a high quality of public transport, than in medium and small municipalities, where private transport is sometimes the only transport alternative. Our result is in line with the values obtained in aggregate demand models with respect to long-term income elasticity[7]. As far as we are aware, very few studies are available on petrol demand at household level, and none of them presents long-term income elasticity[8]. Studies using micro data concentrate on vehicle use and provide elasticities with respect to the number of kilometres travelled. In this context, De Jong (1990) reports for the Netherlands a non-conditional elasticity of 0.63. The higher magnitude estimated using Spanish data could be explained by two facts. First, petrol consumption elasticity with respect to income captures both an increase in the number of kilometres travelled and a change to cars with higher horsepower, which implies higher petrol consumption per kilometre travelled[9]. Second, Spain's GDP per head was 79% of the EU average in 1990, while in vehicles *per capita* that percentage was 77%. If income elasticity decreases with the level of income, as most studies show, a higher value of the Spanish elasticity should be expected.

Short-term income elasticity lies around 0.59 and decreases very slightly with the level of income. This implies that, on average, the direct effect accounts for 55% of the total long-term adjustment to income changes, whereas the rest is due to changes in the number of vehicles. This percentage is similar to that obtained by De Jong (1990) and has also been suggested by Dahl and Sterner (1991) from aggregate studies. Moreover, income elasticity decreases with the number of vehicles in the household: it ranges from 0.61 in families with one vehicle to 0.45 in families with three or more vehicles.

Again, the elasticity values are in line with those obtained in aggregate studies once we take into account that in our study households with no vehicles are excluded from the sample[10]. Evidence based on micro data is scarcer. Kayser (1999) reports a short–term income elasticity of 0.49, while Dahl and Sterner (1991) present an average elasticity of household studies of 0.41. On the other hand, Schmalensee and Stoker (1999) estimate a

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7 Dahl and Sterner (1991) provide a survey of petrol demand elasticities and they conclude that long-run income elasticity ranges between 1.16 and 1.32 whereas Espey (1998) provides a mean value of 0.81.

8 Surveyed studies on gasoline demand at household level include Archibald and Gillingham (1980), (1981), Berkowitz, Gallini, Miller and Wolfe (1990), Puller and Greening (1999), Kayser (1999) and Schmalensee and Stoker (1999).

9 Several authors have reported the high sensitivity of vehicle-type with respect to income. See, for instance, Mannering and Winston (1985) and McCarthy (1996).

10 Dahl and Sterner report short run income elasticities varying from 0.39 to 0.52; Espey (1998) reports a mean value of 0.39.

much lower value, given that part of their income effect is captured by the number of driving licences in the household.

According to our results, in the long-term consumption is elastic with respect to income, which explains the substantial growth in petrol consumption in Spain in the last decade. This growth is due both to an increase in the number of cars per head of population and to an increase in the number of kilometres travelled per vehicle. In fact, the number of cars per thousand inhabitants in Spain has increased by 35% between 1990 and 1998, while the number of kilometres run has grown by 50%. Obviously those figures cannot be projected into the future, as there is a saturation level for the number of vehicles in a household. Therefore, we should expect lower values for income elasticities as real income rises.

6. REDISTRIBUTIVE EFFECTS OF PETROL TAXATION

The evaluation of the redistributive effects of petrol taxation has usually consisted in the comparison of the proportion of income spent on petrol by the households at the extremes of the income distribution (see, for instance, Chernick and Reschovsky [1997] or Casler and Rafiqui [1993]). The main disadvantage of such a method is that it does not take into account what happens in the rest of the distribution

We evaluate the redistributive effects that petrol taxation generates, using an index that considers the whole income distribution and using household expenditure as a proxy of lifetime income. Given that city size has been shown to have a significant impact on petrol consumption patterns, our redistribution analysis will be conditioned on that variable. As previously pointed out, the lack of representativeness of the EPF subsamples for the largest cities forces us to rely on simulation techniques. The following analysis is based on a definition of standard household that will be used to evaluate the redistributive effects by modifying its income and place of residence in order to simulate the changes in petrol taxes paid. Defining the standard household is always somewhat subjective, but, in any case, the models estimated so far make it perfectly possible to carry out the analysis employing alternative types of households.

The standard household is defined as the one adopted when computing income elasticities in Section 5. We simulate the change in petrol consumption that takes place in such a household when income rises from €6,010 to €60,100 in steps of €3,005. We repeat this simulation for each of the areas of residence considered in the analysis.

Simulation is carried out in the following steps. The ordered probit model inTable 2 provides the probabilities of different car ownership levels. We assume that owning no car implies zero petrol consumption. The data indicate that households with more than two cars always have positive petrol expenditure. For those cases, therefore, the infrequent purchase problem does not apply. When one or two cars are owned, Tables 4 and 5 provide the probabilities that a positive amount is spent on petrol. Petrol consumption is provided by the results shown in Table 6. Taxation as a result of petrol consumption is computed using the share of taxes in the price of 98 oct. petrol in 1990. In that year the customer price of €0.49 consisted in 63% taxes, as the following breakdown shows:

	euros	**as % of the final price**
Price without taxes	0.18	37 %
Excise duty	0.26	53 %
VAT	0.05	10 %
Total taxes	0.31	63 %
Price with taxes	0.49	100 %

We therefore calculate the taxes paid by the household as 63% of petrol expenditure. Table 8 shows the results of the simulations for each household income level and place of residence. The columns show the probabilities that the household owns one, two or more than two cars, the expected number of cars, the probability of positive petrol expenditure when one or two cars are owned, expected petrol consumption and taxes paid. These last two variables are shown both in money terms and as a percentage of household income.

Both the probability that the household owns one or more cars and the expected number of cars increase with income. The probability that a household has only one car rises with income up to a certain level - which varies in different municipalities - and from then on the likelihood that two cars are owned increases. It is also observed that, for a fixed income level, car ownership rises as the size of the city of residence falls. Madrid and

Barcelona show the lowest car ownership levels, while the expected number of cars is maximum in localities of fewer than 10,000 inhabitants.

In absolute terms, petrol consumption rises continuously with income. Similarly to car ownership, petrol consumption is higher in smaller localities, where private transport is often the only available transport alternative.

The changes of the average rate of petrol taxation reveal a progressive effect in the lowest income levels, given that the share of taxes rises with income. This effect, however, vanishes when a certain income level is reached. This pattern is the same that has been observed in Section 3.3 using the whole EPF sample. Table 8 makes it possible to observe that the turning point is higher in larger cities. In the smallest localities it takes place between €9,000 and €12,000, while in Barcelona and Madrid petrol taxes are progressive for households with incomes of up to €15,000 or €18,000. The smaller the municipality, the earlier the progressive effect of petrol taxation disappears.

The analysis so far does not allow us to answer the question of whether the overall redistributive effect of petrol taxation is progressive or regressive. It is clear that for the lower income level it is progressive, while for the higher it is regressive. In order to provide a clear answer we employ an index of redistribution.

The redistributive effect of a tax is related to the impact it has in terms of reduction of vertical inequality in income distribution. A classical index used to measure such an effect is that of Reynolds-Smolensky (RS), defined as the change in the Gini index. A positive RS implies that as a consequence of the payment of the tax the Gini index falls, so that income distribution is more equal and the tax can be considered progressive. On the contrary, a negative RS would imply regressive taxation.

However, the calculation of vertical inequality indexes requires knowledge of how income is distributed. It has already been noted that the size of the EPF subsamples makes it impossible to obtain reasonable approximations to such distributions at city level. So, we assume that the distribution of income (but not its level) for the standard households we are interested in can be approximated by the distribution of income for those households at national level, as shown by the EPF.

The redistributive effects generated by petrol taxes in each city are shown in Table 9. It should be noted that the size of the redistributive effects is relatively small. This is the expected result, given the share of petrol expenditure in household budgets. Pazos and Salas (1997) measure the redistributive effects of all types of public subsidies in Spain and find an RS value of 0.18. In any case, low RS values do not imply that redistributive effects do not exist. In fact, they do exist, and as Table 9 shows, they differ among localities. In the largest municipalities, petrol taxes reduce inequality in income distribution, while in the smallest ones the opposite effect is observed. In Barcelona and Madrid the RS indexes amount to 0.0005, while in the other large cities included in the sample the falls to 0.0001. In cities of less than half a million inhabitants, petrol taxes have a regressive effect, which is most intense in the smallest municipalities.

7. CONCLUSIONS

The conclusions of this paper are twofold. On the one hand, they relate to the methodology employed and the estimated elasticities using micro data and, on the other one, to the empirical results obtained about the redistributive effects of petrol taxation.

Methodologically, the study estimates transport expenditure according to the households' characteristics and permanent income, proxied by current expenditure. The analysis of petrol expenditure and the redistributive effects of its taxation faces the difficulty that, although the EPF provides a large sample and taxation is common to all citizens, both car ownership and car use vary with the locality of residence. *Ceteris paribus*, households in large urban centres with better availability of public transport are less likely to own cars than those in rural areas, whose potential mobility largely depends on having access to a private car. Another methodological issue stems from the fact that the EPF collects petrol expenditure only during one week. It is possible that during that period petrol expenditure and consumption differ. This problem has been solved with the help of a purchase frequency model, where consumption is estimated from observed expenditure. Once car ownership and a corrected measure of petrol consumption have been estimated, we use information on petrol taxation to evaluate the redistributive effect of the tax. A final methodological contribution that needs to be pointed out is that the modelling exercises make it possible to evaluate alternative hypothetical scenarios. In our case, such a model has been used to simulate the case of a standard household with different income levels and places of residence. The characteristics of the household can be easily modified, and in this way the model can be used to analyse the redistributive effects on alternative households and/or of different tax rules.

As regards the redistributive effects of petrol taxation, it should be pointed out that *a priori* they look relatively ambiguous. For the lowest income deciles, the share of petrol expenditure increases with income, and thus the tax can be regarded as progressive. However, after a certain income level, which is not the same for all localities, the tax is regressive. The calculation of a common redistribution index has shown that in the largest cities the overall result points to a progressive effect, with petrol taxation reducing inequality in income distribution. This effect is less intense, the smaller the cities considered. In those with fewer than 500,000 residents the effects prove to be regressive. For the smallest municipalities we find the most regressive effects. The calculation of such effects has made it clear that besides the effect that petrol taxation may have on controlling demand, redistributive effects exist. Moreover, such effects are not common to all localities.

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Table 1. Descriptive statistics

Variables	Average	St. dev.
EXPENDITURE (ptas)	14,576.35	10,027.89
PETROL (ptas)	828.52	684.57
ADULT	2.17	1.38
RETIRED	0.44	0.71
CHILDREN	0.79	1.07
EMPLOYED	1.04	0.91
EDUCATION	6.51	4.45
AGE (years)	53.0	15.64
CARS	0.74	0.67
MOTORCYCLES	0.18	0.42
QUALITY	143	68.23

Cars per household	Households	%
no car	7,721	37
1 car	11,106	53
2 cars	1,885	9
3 or more cars	222	1

Households with positive petrol consumption: 12,322

Sample distribution by municipality size	
Madrid	508
Barcelona	226
Sevilla	277
Valencia	299
Malaga	306
Zaragoza	342
Large municipalities	7,901
Medium municipalities	5,082
Small municipalities	5,993
Sample size	20,934

Table 2. Probabilities of car ownership levels. Estimation results.

Method: ML - Ordered Probit

Included observations: 20934
Number of ordered indicator values: 4
Convergence achieved after 7 iterations
Covariance matrix computed using second derivatives

	Coefficient	Std. Error	z-Statistic	Prob.
SEVILLA, ZARAGOZA VALENCIA, MÁLAGA	0.275418	0.058758	4.687299	0.0000
LARGE	0.342919	0.049683	6.902195	0.0000
MEDIUM	0.408983	0.050450	8.106725	0.0000
SMALL	0.492853	0.051818	9.511229	0.0000
LOG(INCOME)	0.863181	0.018917	45.62918	0.0000
ADULTS	0.121114	0.009226	13.12755	0.0000
EMPLOYED1	0.557898	0.027111	20.57840	0.0000
EMPLOYED2	0.781293	0.031866	24.51815	0.0000
AGE1	-0.345182	0.072443	-4.764878	0.0000
AGE2	0.059847	0.027406	2.183733	0.0290
AGE3	-0.104630	0.023773	-4.401133	0.0000
AGE4	-0.269879	0.029850	-9.041181	0.0000
EDUCATION	0.037407	0.002288	16.34844	0.0000
QUALITY	0.000362	0.000140	2.581451	0.0098
Limit Points				
LIMIT_1:C(15)	13.38716	0.273325	48.97890	0.0000
LIMIT_2:C(16)	15.60911	0.278537	56.03970	0.0000
LIMIT_3:C(17)	16.89787	0.282059	59.90906	0.0000
Akaike info criterion	1.423316	Schwarz criterion		1.429772
Log likelihood	-14880.85	Hannan-Quinn criter.		1.425424
Restr. log likelihood	-20288.49	Avg. log likelihood		-0.710846
LR statistic (14 df)	10815.27	LR index (Pseudo-R2)		0.266537
Probability(LR stat)	0.000000			

Table 3. Car ownership probabilities according to the city of residence.

Municipality	No car	Probability of owning: 1 car	2 cars	3+ cars	Expected number of cars
Madrid, Barcelona	0,277	0,672	0,050	0,002	0,78
Sevilla, Valencia, Zaragoza, Málaga	0,193	0,719	0,084	0,004	0,90
Large municipalities	0,175	0,726	0,094	0,005	0,93
Medium municipalities	0,158	0,731	0,105	0,006	0,96
Small municipalities	0,139	0,733	0,120	0,008	1,00

Probabilities for a household with two adults, one worker, income of 15,025 euros and head of household between 35 and 55 years old with 11 years of education.

Table 4. Probability model of positive weekly expenditure on petrol for households with one car. Estimation results.

Dependent Variable: PROBABILITY OF POSITIVE PETROL EXPENDITURE
Method: ML – Binary Probit
Included observations: 11106
Convergence achieved after 6 iterations
Covariance matrix computed using second derivatives

Variable0	Coefficient	Std. Error	z-Statistic	Prob.
C	-5.628054	0.420978	-13.36900	0.0000
LOG(INCOME)	0.404710	0.029179	13.86978	0.0000
ADULTS	0.142251	0.016227	8.766522	0.0000
EMPLOYED1	0.176764	0.044174	4.001588	0.0001
EMPLOYED2	0.163196	0.050583	3.226319	0.0013
AGE1	0.289494	0.123763	2.339097	0.0193
AGE2	0.207347	0.039132	5.298670	0.0000
AGE3	0.004848	0.038940	0.124488	0.9009
AGE4	0.044314	0.049624	0.892986	0.3719

Mean dependent var	0.796326	S.D. dependent var	0.402747
S.E. of regression	0.392225	Akaike info criterion	0.966421
Sum squared resid	1707.168	Schwarz criterion	0.972349
Log likelihood	-5357.535	Hannan-Quinn criter.	0.968417
Restr. Log likelihood	-5613.564	Avg. log likelihood	-0.482400
LR statistic (8 df)	512.0569	McFadden R-squared	0.045609
Probability(LR stat)	0.000000		

Table 5. Probability model of positive weekly expenditure on petrol for households with two cars. Estimation results.

Dependent Variable: PROBABILITY OF POSITIVE PETROL EXPENDITURE
Method: ML - Binary Probit
Included observations: 1885 after adjusting endpoints
Convergence achieved after 6 iterations
Covariance matrix computed using second derivatives

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	-3.426458	1.302649	-2.630377	0.0085
LOG(INCOME)	0.260346	0.086794	2.999578	0.0027
ADULTS	0.196943	0.038950	5.056253	0.0000
EMPLOYED1	0.250660	0.178048	1.407823	0.1592
EMPLOYED2	0.286171	0.176541	1.620991	0.1050

Mean dependent var	0.908223	S.D. dependent var	0.288788
S.E. of regression	0.284953	Akaike info criterion	0.591669
Sum squared resid	152.6528	Schwarz criterion	0.606368
Log likelihood	-552.6477	Hannan-Quinn criter.	0.597082
Restr. log likelihood	-577.9983	Avg. log likelihood	-0.293182
LR statistic (4 df)	50.70130	McFadden R-squared	0.043859
Probability(LR stat)	2.58E-10		

Table 6. Estimation results of petrol consumption equation

Dependent Variable: log(petrol consumption)
Method: Least Squares
Included observations: 10766
White Heteroskedasticity-Consistent Standard Errors & Covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	2.028765	0.229481	8.840674	0.0000
LOG (INCOME)	0.608801	0.015793	38.54795	0.0000
ADULTS	0.059956	0.006927	8.655974	0.0000
EMPLOYED1	0.150492	0.022269	6.758064	0.0000
EMPLOYED2	0.204096	0.024592	8.299324	0.0000
SMALL	0.062214	0.014884	4.179828	0.0000
AGE1	0.207625	0.054387	3.817575	0.0001
AGE2	0.170981	0.017228	9.924448	0.0000
AGE3	-0.015170	0.017151	-0.884538	0.3764
AGE4	-0.030852	0.023159	-1.332171	0.1828
D2	2.368452	0.573095	4.132736	0.0000
D2 * LOG INCOME	-0.136461	0.038114	-3.580304	0.0003
D3	3.173643	1.701619	1.865072	0.0622
D3 * LOG INCOME	-0.163729	0.110645	-1.479761	0.1390

R-squared	0.298796	Mean dependent var	11.46604
Adjusted R-squared	0.297948	S.D. dependent var	0.762417
S.E. of regression	0.638818	Akaike info criterion	1.942905
Sum squared resid	4387.765	Schwarz criterion	1.952377
Log likelihood	-10444.66	F-statistic	352.4322
Durbin-Watson stat	1.764601	Prob(F-statistic)	0.000000

D2: Dummy variable. 1 for values with two cars, 0 otherwise.
D3: Dummy variable. 1 for values with three or more cars, 0 otherwise

Table 7. Long and short-term income elasticities

Long-term elasticities

	Income level			
Place of residence	High	Medium-high	Medium-low	Low
Madrid, Barcelona	1.35	1.17	1.04	0.89
Sevilla, Valencia, Zaragoza, Malaga	1.21	1.05	0.94	0.83
Large municipalities	1.17	1.02	0.92	0.81
Medium municipalities	1.14	1.00	0.90	0.80
Small municipalities	1.11	0.97	0.88	0.79

Short -term elasticities

	Income level			
Place of residence	High	Medium-high	Medium-low	Low
Madrid, Barcelona	0.60	0.59	0.59	0.58
Sevilla, Valencia, Zaragoza, Malaga	0.59	0.59	0.58	0.57
Large municipalities	0.59	0.59	0.58	0.57
Medium municipalities	0.59	0.59	0.58	0.56
Small municipalities	0.59	0.58	0.57	0.56

Table 8. Simulation results of car ownership, petrol consumption and taxation

Madrid

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
6,010	0.40	0.01	0.00	0.42	0.66	0.79	138	87	2.30%	1.45%
9,015	0.53	0.02	0.00	0.57	0.72	0.82	239	150	2.65%	1.67%
12,020	0.61	0.03	0.00	0.68	0.76	0.84	336	212	2.79%	1.76%
15,025	0.67	0.05	0.00	0.77	0.79	0.85	428	270	2.85%	1.80%
18,030	0.70	0.06	0.00	0.84	0.81	0.86	515	325	2.86%	1.80%
21,035	0.72	0.08	0.00	0.89	0.82	0.87	598	377	2.84%	1.79%
24,040	0.73	0.10	0.01	0.95	0.84	0.88	676	426	2.81%	1.77%
27,046	0.73	0.12	0.01	0.99	0.85	0.89	750	472	2.77%	1.75%
30,051	0.73	0.14	0.01	1.03	0.86	0.89	820	517	2.73%	1.72%
33,056	0.73	0.15	0.01	1.07	0.87	0.90	887	559	2.68%	1.69%
36,061	0.72	0.17	0.01	1.11	0.87	0.90	952	600	2.64%	1.66%
39,066	0.71	0.19	0.02	1.14	0.88	0.90	1,014	639	2.59%	1.63%
42,071	0.71	0.20	0.02	1.17	0.89	0.91	1,073	676	2.55%	1.61%
45,076	0.70	0.22	0.02	1.20	0.89	0.91	1,131	712	2.51%	1.58%
48,081	0.68	0.23	0.03	1.23	0.90	0.91	1,186	747	2.47%	1.55%
51,086	0.67	0.25	0.03	1.25	0.90	0.91	1,240	781	2.43%	1.53%
54,091	0.66	0.26	0.03	1.28	0.91	0.92	1,292	814	2.39%	1.51%
57,096	0.65	0.27	0.04	1.30	0.91	0.92	1,343	846	2.35%	1.48%
60,101	0.64	0.28	0.04	1.33	0.91	0.92	1,392	877	2.32%	1.46%

Barcelona

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
6,010	0.41	0.01	0.00	0.42	0.66	0.79	139	87	2.31%	1.46%
9,015	0.53	0.02	0.00	0.57	0.72	0.82	239	151	2.65%	1.67%
12,020	0.61	0.03	0.00	0.68	0.76	0.84	337	212	2.80%	1.76%
15,025	0.67	0.05	0.00	0.77	0.79	0.85	429	270	2.86%	1.80%
18,030	0.70	0.06	0.00	0.84	0.81	0.86	516	325	2.86%	1.80%
21,035	0.72	0.08	0.00	0.90	0.82	0.87	599	377	2.85%	1.79%
24,040	0.73	0.10	0.01	0.95	0.84	0.88	676	426	2.81%	1.77%
27,046	0.73	0.12	0.01	0.99	0.85	0.89	750	473	2.77%	1.75%
30,051	0.73	0.14	0.01	1.03	0.86	0.89	821	517	2.73%	1.72%
33,056	0.73	0.15	0.01	1.07	0.87	0.90	888	560	2.69%	1.69%
36,061	0.72	0.17	0.01	1.11	0.87	0.90	953	600	2.64%	1.66%
39,066	0.71	0.19	0.02	1.14	0.88	0.90	1,015	639	2.60%	1.64%
42,071	0.70	0.20	0.02	1.17	0.89	0.91	1,074	677	2.55%	1.61%
45,076	0.69	0.22	0.02	1.20	0.89	0.91	1,132	713	2.51%	1.58%
48,081	0.68	0.23	0.03	1.23	0.90	0.91	1,187	748	2.47%	1.56%
51,086	0.67	0.25	0.03	1.25	0.90	0.91	1,241	782	2.43%	1.53%
54,091	0.66	0.26	0.03	1.28	0.91	0.92	1,293	815	2.39%	1.51%
57,096	0.65	0.27	0.04	1.30	0.91	0.92	1,344	847	2.35%	1.48%
60,101	0.64	0.28	0.04	1.33	0.91	0.92	1,393	878	2.32%	1.46%

table 8 (continued)

Valencia

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
6,010	0.51	0.01	0.00	0.54	0.66	0.79	176	111	2.93%	1.85%
9,015	0.62	0.03	0.00	0.69	0.72	0.82	288	181	3.19%	2.01%
12,020	0.68	0.06	0.00	0.80	0.76	0.84	391	247	3.26%	2.05%
15,025	0.72	0.08	0.00	0.89	0.79	0.85	487	307	3.24%	2.04%
18,030	0.73	0.10	0.01	0.96	0.81	0.86	577	363	3.20%	2.02%
21,035	0.73	0.13	0.01	1.02	0.82	0.87	660	416	3.14%	1.98%
24,040	0.73	0.15	0.01	1.07	0.84	0.88	739	466	3.07%	1.94%
27,046	0.72	0.18	0.02	1.12	0.85	0.89	813	512	3.01%	1.89%
30,051	0.71	0.20	0.02	1.16	0.86	0.89	884	557	2.94%	1.85%
33,056	0.69	0.22	0.02	1.20	0.87	0.90	952	599	2.88%	1.81%
36,061	0.68	0.24	0.03	1.24	0.87	0.90	1,016	640	2.82%	1.78%
39,066	0.66	0.26	0.03	1.27	0.88	0.90	1,078	679	2.76%	1.74%
42,071	0.65	0.27	0.04	1.31	0.89	0.91	1,137	717	2.70%	1.70%
45,076	0.63	0.29	0.04	1.34	0.89	0.91	1,195	753	2.65%	1.67%
48,081	0.61	0.31	0.05	1.37	0.90	0.91	1,250	788	2.60%	1.64%
51,086	0.60	0.32	0.05	1.40	0.90	0.91	1,304	822	2.55%	1.61%
54,091	0.58	0.33	0.06	1.43	0.91	0.92	1,356	855	2.51%	1.58%
57,096	0.57	0.35	0.06	1.45	0.91	0.92	1,407	886	2.46%	1.55%
60,101	0.55	0.36	0.07	1.48	0.91	0.92	1,456	917	2.42%	1.53%

Sevilla

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
6,010	0.51	0.01	0.00	0.54	0.66	0.79	176	111	2.93%	1.85%
9,015	0.62	0.03	0.00	0.69	0.72	0.82	287	181	3.19%	2.01%
12,020	0.68	0.06	0.00	0.80	0.76	0.84	391	246	3.25%	2.05%
15,025	0.72	0.08	0.00	0.89	0.79	0.85	487	307	3.24%	2.04%
18,030	0.73	0.10	0.01	0.96	0.81	0.86	577	363	3.20%	2.02%
21,035	0.73	0.13	0.01	1.02	0.82	0.87	660	416	3.14%	1.98%
24,040	0.73	0.15	0.01	1.07	0.84	0.88	739	466	3.07%	1.94%
27,046	0.72	0.18	0.02	1.12	0.85	0.89	813	512	3.01%	1.89%
30,051	0.71	0.20	0.02	1.16	0.86	0.89	884	557	2.94%	1.85%
33,056	0.69	0.22	0.02	1.20	0.87	0.90	951	599	2.88%	1.81%
36,061	0.68	0.24	0.03	1.24	0.87	0.90	1,016	640	2.82%	1.77%
39,066	0.66	0.26	0.03	1.27	0.88	0.90	1,078	679	2.76%	1.74%
42,071	0.65	0.27	0.04	1.31	0.89	0.91	1,137	717	2.70%	1.70%
45,076	0.63	0.29	0.04	1.34	0.89	0.91	1,195	753	2.65%	1.67%
48,081	0.61	0.31	0.05	1.37	0.90	0.91	1,250	788	2.60%	1.64%
51,086	0.60	0.32	0.05	1.40	0.90	0.91	1,304	822	2.55%	1.61%
54,091	0.58	0.33	0.06	1.43	0.91	0.92	1,356	854	2.51%	1.58%
57,096	0.57	0.35	0.06	1.45	0.91	0.92	1,407	886	2.46%	1.55%
60,101	0.55	0.36	0.07	1.48	0.91	0.92	1,456	917	2.42%	1.53%

table 8 (continued)

Málaga

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
6,010	0.51	0.01	0.00	0.54	0.66	0.79	176	111	2.94%	1.85%
9,015	0.62	0.03	0.00	0.69	0.72	0.82	288	181	3.19%	2.01%
12,020	0.68	0.06	0.00	0.80	0.76	0.84	391	247	3.26%	2.05%
15,025	0.72	0.08	0.00	0.89	0.79	0.85	488	307	3.24%	2.04%
18,030	0.73	0.11	0.01	0.96	0.81	0.86	577	363	3.20%	2.02%
21,035	0.73	0.13	0.01	1.02	0.82	0.87	661	416	3.14%	1.98%
24,040	0.73	0.15	0.01	1.07	0.84	0.88	739	466	3.07%	1.94%
27,046	0.72	0.18	0.02	1.12	0.85	0.89	814	513	3.01%	1.90%
30,051	0.71	0.20	0.02	1.16	0.86	0.89	884	557	2.94%	1.85%
33,056	0.69	0.22	0.02	1.20	0.87	0.90	952	600	2.88%	1.81%
36,061	0.68	0.24	0.03	1.24	0.87	0.90	1,016	640	2.82%	1.78%
39,066	0.66	0.26	0.03	1.28	0.88	0.90	1,078	679	2.76%	1.74%
42,071	0.65	0.27	0.04	1.31	0.89	0.91	1,138	717	2.70%	1.70%
45,076	0.63	0.29	0.04	1.34	0.89	0.91	1,195	753	2.65%	1.67%
48,081	0.61	0.31	0.05	1.37	0.90	0.91	1,251	788	2.60%	1.64%
51,086	0.60	0.32	0.05	1.40	0.90	0.91	1,304	822	2.55%	1.61%
54,091	0.58	0.33	0.06	1.43	0.91	0.92	1,356	855	2.51%	1.58%
57,096	0.57	0.35	0.06	1.45	0.91	0.92	1,407	887	2.46%	1.55%
60,101	0.55	0.36	0.07	1.48	0.91	0.92	1,456	918	2.42%	1.53%

Zaragoza

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
6,010	0.51	0.01	0.00	0.54	0.66	0.79	177	112	2.95%	1.86%
9,015	0.62	0.03	0.00	0.69	0.72	0.82	289	182	3.20%	2.02%
12,020	0.69	0.06	0.00	0.81	0.76	0.84	392	247	3.26%	2.06%
15,025	0.72	0.08	0.00	0.89	0.79	0.85	489	308	3.25%	2.05%
18,030	0.73	0.11	0.01	0.96	0.81	0.86	578	364	3.21%	2.02%
21,035	0.73	0.13	0.01	1.02	0.82	0.87	662	417	3.15%	1.98%
24,040	0.73	0.15	0.01	1.07	0.84	0.88	740	466	3.08%	1.94%
27,046	0.72	0.18	0.02	1.12	0.85	0.89	815	513	3.01%	1.90%
30,051	0.71	0.20	0.02	1.16	0.86	0.89	885	558	2.95%	1.86%
33,056	0.69	0.22	0.02	1.21	0.87	0.90	953	600	2.88%	1.82%
36,061	0.68	0.24	0.03	1.24	0.87	0.90	1,017	641	2.82%	1.78%
39,066	0.66	0.26	0.03	1.28	0.88	0.90	1,079	680	2.76%	1.74%
42,071	0.64	0.28	0.04	1.31	0.89	0.91	1,139	717	2.71%	1.71%
45,076	0.63	0.29	0.04	1.34	0.89	0.91	1,196	754	2.65%	1.67%
48,081	0.61	0.31	0.05	1.37	0.90	0.91	1,252	789	2.60%	1.64%
51,086	0.60	0.32	0.05	1.40	0.90	0.91	1,306	823	2.56%	1.61%
54,091	0.58	0.33	0.06	1.43	0.91	0.92	1,358	855	2.51%	1.58%
57,096	0.56	0.35	0.07	1.46	0.91	0.92	1,408	887	2.47%	1.55%
60,101	0.55	0.36	0.07	1.48	0.91	0.92	1,458	918	2.43%	1.53%

Table 8 (continued)

Large municipalities

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
6,010	0.53	0.02	0.00	0.57	0.66	0.79	186	117	3.10%	1.95%
9,015	0.64	0.04	0.00	0.72	0.72	0.82	300	189	3.33%	2.10%
12,020	0.70	0.06	0.00	0.83	0.76	0.84	405	255	3.37%	2.12%
15,025	0.72	0.09	0.00	0.92	0.79	0.85	502	316	3.34%	2.10%
18,030	0.73	0.12	0.01	0.99	0.81	0.86	591	373	3.28%	2.07%
21,035	0.73	0.14	0.01	1.05	0.82	0.87	675	425	3.21%	2.02%
24,040	0.72	0.17	0.01	1.10	0.84	0.88	754	475	3.14%	1.98%
27,046	0.71	0.19	0.02	1.15	0.85	0.89	829	522	3.06%	1.93%
30,051	0.70	0.22	0.02	1.20	0.86	0.89	900	567	2.99%	1.89%
33,056	0.68	0.24	0.03	1.24	0.87	0.90	967	609	2.93%	1.84%
36,061	0.66	0.26	0.03	1.28	0.87	0.90	1,032	650	2.86%	1.80%
39,066	0.64	0.28	0.04	1.31	0.88	0.90	1,094	689	2.80%	1.76%
42,071	0.63	0.29	0.04	1.35	0.89	0.91	1,153	727	2.74%	1.73%
45,076	0.61	0.31	0.05	1.38	0.89	0.91	1,211	763	2.69%	1.69%
48,081	0.59	0.32	0.06	1.41	0.90	0.91	1,266	798	2.63%	1.66%
51,086	0.57	0.34	0.06	1.44	0.90	0.91	1,320	832	2.58%	1.63%
54,091	0.56	0.35	0.07	1.47	0.91	0.92	1,372	865	2.54%	1.60%
57,096	0.54	0.36	0.07	1.49	0.91	0.92	1,423	897	2.49%	1.57%
60,101	0.53	0.37	0.08	1.52	0.91	0.92	1,472	928	2.45%	1.54%

Medium municipalities

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
6,010	0.55	0.02	0.00	0.60	0.66	0.79	196	123	3.26%	2.05%
9,015	0.66	0.04	0.00	0.75	0.72	0.82	311	196	3.45%	2.17%
12,020	0.71	0.07	0.00	0.86	0.76	0.84	417	263	3.47%	2.19%
15,025	0.73	0.10	0.01	0.95	0.79	0.85	515	324	3.43%	2.16%
18,030	0.73	0.13	0.01	1.02	0.81	0.86	605	381	3.35%	2.11%
21,035	0.73	0.16	0.01	1.08	0.82	0.87	689	434	3.28%	2.06%
24,040	0.72	0.18	0.02	1.14	0.84	0.88	768	484	3.19%	2.01%
27,046	0.70	0.21	0.02	1.18	0.85	0.89	843	531	3.12%	1.96%
30,051	0.68	0.23	0.03	1.23	0.86	0.89	914	576	3.04%	1.92%
33,056	0.66	0.26	0.03	1.27	0.87	0.90	981	618	2.97%	1.87%
36,061	0.65	0.28	0.04	1.31	0.87	0.90	1,046	659	2.90%	1.83%
39,066	0.63	0.29	0.04	1.35	0.88	0.90	1,108	698	2.84%	1.79%
42,071	0.61	0.31	0.05	1.38	0.89	0.91	1,168	736	2.78%	1.75%
45,076	0.59	0.33	0.06	1.41	0.89	0.91	1,225	772	2.72%	1.71%
48,081	0.57	0.34	0.06	1.45	0.90	0.91	1,281	807	2.66%	1.68%
51,086	0.55	0.36	0.07	1.48	0.90	0.91	1,335	841	2.61%	1.65%
54,091	0.54	0.37	0.08	1.50	0.91	0.92	1,387	874	2.56%	1.62%
57,096	0.52	0.38	0.08	1.53	0.91	0.92	1,438	906	2.52%	1.59%
60,101	0.50	0.39	0.09	1.56	0.91	0.92	1,488	937	2.48%	1.56%

table 8 (continued)

Small municipalities

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
6,010	0.58	0.03	0.00	0.63	0.66	0.79	220	139	3.66%	2.30%
9,015	0.68	0.05	0.00	0.79	0.72	0.82	345	217	3.83%	2.41%
12,020	0.72	0.08	0.00	0.90	0.76	0.84	459	289	3.82%	2.41%
15,025	0.73	0.12	0.01	0.99	0.79	0.85	564	355	3.76%	2.37%
18,030	0.73	0.15	0.01	1.06	0.81	0.86	661	417	3.67%	2.31%
21,035	0.72	0.18	0.02	1.12	0.82	0.87	752	473	3.57%	2.25%
24,040	0.70	0.21	0.02	1.18	0.84	0.88	836	527	3.48%	2.19%
27,046	0.68	0.23	0.03	1.23	0.85	0.89	917	577	3.39%	2.14%
30,051	0.66	0.26	0.03	1.27	0.86	0.89	993	625	3.30%	2.08%
33,056	0.64	0.28	0.04	1.31	0.87	0.90	1,065	671	3.22%	2.03%
36,061	0.62	0.30	0.05	1.35	0.87	0.90	1,134	715	3.15%	1.98%
39,066	0.60	0.32	0.05	1.39	0.88	0.90	1,201	756	3.07%	1.94%
42,071	0.58	0.33	0.06	1.43	0.89	0.91	1,265	797	3.01%	1.89%
45,076	0.56	0.35	0.07	1.46	0.89	0.91	1,326	835	2.94%	1.85%
48,081	0.54	0.36	0.07	1.49	0.90	0.91	1,385	873	2.88%	1.82%
51,086	0.52	0.38	0.08	1.52	0.90	0.91	1,443	909	2.82%	1.78%
54,091	0.51	0.39	0.09	1.55	0.91	0.92	1,499	944	2.77%	1.75%
57,096	0.49	0.40	0.10	1.58	0.91	0.92	1,553	978	2.72%	1.71%
60,101	0.47	0.41	0.11	1.61	0.91	0.92	1,605	1,011	2.67%	1.68%

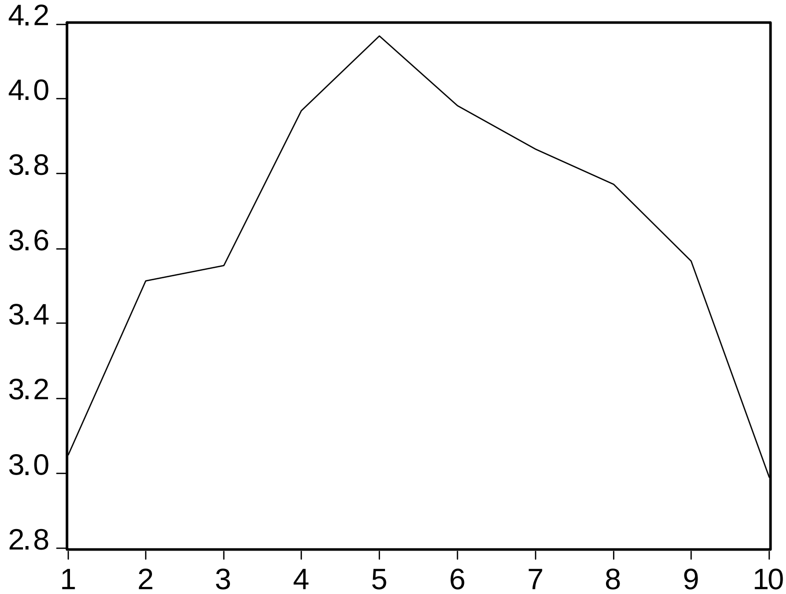
Notes for table 8:

(1) Household income, in euros
(2) Probability of owning one car
(3) Probability of owning two cars
(4) Probability of owning more than two cars
(5) Expected number of cars
(6) Probability of positive petrol consumption when owning one car
(7) Probability of positive petrol consumption when owning two cars
(8) Household petrol consumption, in euros
(9) Household petrol taxes, in euros
(10) Household petrol consumption as percentage of income
(11) Household petrol taxes as percentage of income

Table 10. Redistributive effects of petrol taxation on the standard household

Municipality	**Initial Gini**	**Final Gini**	**RS index**
Madrid	0.2576	0.2571	0.0005
Barcelona	0.2576	0.2571	0.0005
Malaga	0.2576	0.2575	0.0001
Zaragoza	0.2576	0.2576	0.0001
Sevilla	0.2576	0.2575	0.0001
Valencia	0.2576	0.2575	0.0001
Large municipalities	0.2576	0.2577	-0.0001
Medium municipalities	0.2576	0.2578	-0.0002
Small municipalities	0.2576	0.2579	-0.0003

Figure 1. Share of petrol consumption on total household expenditure (expenditure deciles)



Appendix

Table A1

Dependent Variable: LOG(CONGAS)
Method: Least Squares
Date: 03/07/01 Time: 12:29
Sample(adjusted): 1 20931
Included observations: 10766
Excluded observations: 10165 after adjusting endpoints
White Heteroskedasticity-Consistent Standard Errors & Covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	2.863767	0.579436	4.942333	0.0000
LOG(INCOME)	0.556950	0.037108	15.00883	0.0000
ADULTS	0.054213	0.008787	6.169482	0.0000
EMPLOYED1	0.117276	0.031760	3.692535	0.0002
EMPLOYED2	0.143390	0.039348	3.644125	0.0003
SMALL	0.049300	0.017085	2.885483	0.0039
AGE1	0.225535	0.059359	3.799534	0.0001
AGE2	0.163816	0.018800	8.713805	0.0000
AGE3	-0.017736	0.020352	-0.871482	0.3835
AGE4	-0.026389	0.028616	-0.922174	0.3565
D2	2.855902	0.649330	4.398227	0.0000
D2*LOG(INCOME)	-0.164008	0.041673	-3.935585	0.0001
D2*ADULTS	-0.002599	0.016192	-0.160532	0.8725
D2*EMPLOYED1	-0.012076	0.096686	-0.124904	0.9006
D2*EMPLOYED2	0.068326	0.098024	0.697036	0.4858
D2*SMALL	0.034758	0.039234	0.885932	0.3757
D2*AGE1	-0.075503	0.164152	-0.459956	0.6456
D2*AGE2	-0.032898	0.058797	-0.559524	0.5758
D2*AGE3	0.036475	0.042960	0.849038	0.3959
D2*AGE4	0.124500	0.064180	1.939846	0.0524
D3	3.049309	1.735565	1.756954	0.0790
D3*LOG(INCOME)	-0.135819	0.113287	-1.198891	0.2306
D3*ADULTS	0.002567	0.038054	0.067458	0.9462
D3*EMPLOYED1	-0.407148	0.180967	-2.249847	0.0245
D3*EMPLOYED2	-0.180948	0.141672	-1.277239	0.2015
D3*SMALL	0.119021	0.106162	1.121130	0.2623
D3*AGE1	0.881120	0.095912	9.186735	0.0000
D3*AGE2	0.025610	0.241661	0.105975	0.9156
D3*AGE3	0.194867	0.102748	1.896558	0.0579
D3*AGE4	0.018540	0.148758	0.124633	0.9008
MILLS RATIO	0.083781	0.052397	1.598971	0.1099

R-squared	0.300343	Mean dependent var	11.46604
Adjusted R-squared	0.298388	S.D. dependent var	0.762417
S.E. of regression	0.638618	Akaike info criterion	1.943853
Sum squared resid	4378.081	Schwarz criterion	1.964828
Log likelihood	-10432.76	F-statistic	153.6079
Durbin-Watson stat	1.766967	Prob(F-statistic)	0.000000

Table A2

Dependent Variable: LOG(CONGAS)
Method: Least Squares
Date: 03/07/01 Time: 12:30
Sample(adjusted): 1 20931
Included observations: 10766
Excluded observations: 10165 after adjusting endpoints
White Heteroskedasticity-Consistent Standard Errors & Covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	2.012636	0.232268	8.665152	0.0000
LOG(INCOME)	0.610622	0.016022	38.11093	0.0000
ADULTS	0.059470	0.008179	7.270621	0.0000
EMPLOYED1	0.151477	0.023293	6.503039	0.0000
EMPLOYED2	0.189946	0.026126	7.270519	0.0000
SMALL	0.055515	0.016573	3.349627	0.0008
AGE1	0.209771	0.058393	3.592427	0.0003
AGE2	0.171310	0.018235	9.394728	0.0000
AGE3	-0.025839	0.019602	-1.318176	0.1875
AGE4	-0.046161	0.025668	-1.798368	0.0721
D2	2.433113	0.593488	4.099685	0.0000
D2*LOG(INCOME)	-0.144836	0.039992	-3.621612	0.0003
D2*ADULTS	-0.001619	0.016132	-0.100382	0.9200
D2*EMPLOYED1	-0.004144	0.096519	-0.042938	0.9658
D2*EMPLOYED2	0.080346	0.097750	0.821950	0.4111
D2*SMALL	0.034778	0.039253	0.886004	0.3756
D2*AGE1	-0.081118	0.164653	-0.492660	0.6223
D2*AGE2	-0.031572	0.058794	-0.536990	0.5913
D2*AGE3	0.031542	0.042822	0.736576	0.4614
D2*AGE4	0.117612	0.064048	1.836297	0.0663
D3	2.547321	1.710414	1.489300	0.1364
D3*LOG(INCOME)	-0.118577	0.112743	-1.051744	0.2929
D3*ADULTS	0.004269	0.037903	0.112621	0.9103
D3*EMPLOYED1	-0.393896	0.180617	-2.180836	0.0292
D3*EMPLOYED2	-0.167643	0.141190	-1.187360	0.2351
D3*SMALL	0.119883	0.105947	1.131542	0.2579
D3*AGE1	0.878289	0.095824	9.165647	0.0000
D3*AGE2	0.033095	0.242041	0.136734	0.8912
D3*AGE3	0.192877	0.102458	1.882497	0.0598
D3*AGE4	0.014552	0.148521	0.097983	0.9219

R-squared	0.300173	Mean dependent var	11.46604
Adjusted R-squared	0.298282	S.D. dependent var	0.762417
S.E. of regression	0.638666	Akaike info criterion	1.943911
Sum squared resid	4379.149	Schwarz criterion	1.964209
Log likelihood	-10434.08	F-statistic	158.7906
Durbin-Watson stat	1.767357	Prob(F-statistic)	0.000000

Table A3

Dependent Variable: LOG(CONGAS)
Method: Least Squares
Date: 03/07/01 Time: 12:31
Sample(adjusted): 1 20931
Included observations: 10766
Excluded observations: 10165 after adjusting endpoints
White Heteroskedasticity-Consistent Standard Errors & Covariance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	2.844454	0.569296	4.996438	0.0000
LOG(INCOME)	0.557422	0.036396	15.31550	0.0000
ADULTS	0.054731	0.007724	7.085833	0.0000
EMPLOYED1	0.117381	0.030813	3.809470	0.0001
EMPLOYED2	0.158201	0.038353	4.124865	0.0000
SMALL	0.056219	0.015458	3.636970	0.0003
AGE1	0.223609	0.055336	4.040932	0.0001
AGE2	0.163730	0.017870	9.162415	0.0000
AGE3	-0.006333	0.018170	-0.348522	0.7275
AGE4	-0.010711	0.026564	-0.403198	0.6868
D2	2.792752	0.633479	4.408592	0.0000
D2*LOG(INCOME)	-0.156768	0.040213	-3.898406	0.0001
D3	3.657970	1.728923	2.115751	0.0344
D3*LOG(INCOME)	-0.181551	0.111222	-1.632325	0.1026
MILLS RATIO	0.080829	0.051806	1.560239	0.1187

R-squared	0.298959	Mean dependent var	11.46604
Adjusted R-squared	0.298046	S.D. dependent var	0.762417
S.E. of regression	0.638773	Akaike info criterion	1.942858
Sum squared resid	4386.744	Schwarz criterion	1.953007
Log likelihood	-10443.40	F-statistic	327.4831
Durbin-Watson stat	1.764336	Prob(F-statistic)	0.000000