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Microsimulating the Effects of Household Energy Price Changes in Spain

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ABSTRACT

In this paper we present a microsimulation model to calculate the effects of hypothetical *ex-ante* price changes in the Spanish energy domain. The model rests on our prior estimation of a demand system which is especially designed for simultaneous analysis of different energy goods and uses household data from 1973 to 1995. Our objective is to obtain in-depth information on the behavioural responses by different types of households, which will allow us to determine the welfare effects of such price changes, their distribution across society and the environmental consequences within the residential sector. Although the model used is able to reproduce any type of price change, we illustrate the paper with an actual simulation of the effects of energy taxes that resemble a 50 Euro tax on CO_2 (carbon dioxide) emissions. The results show a significant response by households, sizeable emission reductions, tax revenues, welfare changes and distributional effects. The simulated policy can thus be considered a feasible option to tackle some of the current and severe inefficiencies in Spanish energy and environmental domains.

Key words: Energy, taxation, demand, Spain

JEL codes: C33, H23, H31

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1. Introduction

A comprehensive quantification of the effects of energy price changes on households is very relevant from both positive and normative points of view. First of all, because of the frequency and magnitude of such changes due to oscillations in primary inputs and/or to the influence of different public policies applied in the field. Secondly, because of the importance of energy products in household consumption and expenditure in developed societies. And finally, because of the significant efficiency and distributional concerns that are associated with household energy price changes.

A positive approach to household energy price changes, able to reproduce in great detail the behavioural effects of different *ex-ante* or *ex-post* scenarios, is essential for any sound economic and distributional assessment of the issue. Yet the normative implications of such evaluations are also of great relevance, both to inform on the effectiveness and equity consequences of public policies that affect prices and therefore on their reforms, and as a way to design compensatory packages to offset the undesirable effects of price shocks.

In fact, there are several forms of public intervention with immediate effects on energy prices. This is the case of tax policies in most developed countries, with high levies on (some) energy goods due to low price elasticities and large revenue-raising capacities. Besides, increasing environmental problems have brought about active policies to include those negative external costs in energy prices through regulations, taxes or permits. Another reason to restrict energy demand through public intervention on prices is strategic, in order to avoid an excessive dependence on foreign stocks of primary inputs.

In this paper we present a microsimulation model which enables us to observe the effects of *ex-ante* hypothetical price changes in the Spanish energy domain. The model rests on our prior estimation of a demand system especially designed for a simultaneous analysis of different energy goods, using household data from 1973 to 1995. Our objective is to obtain in-depth information on the behavioural responses by different types of households, which allows us to determine the welfare effects of such price changes, their distribution across society and the environmental consequences within the residential sector.

There are additional reasons, both general and country-specific, to carry out this research with a focus on residential energy consumers. Among the former we should include the ongoing trend to concentrate the burden of energy price rises in households, to avoid effects on competitiveness (see Ekins and Speck, 1999) as well as the social unrest caused by steep and sudden price increases such as those seen in the last few years. Indeed, the profile of energy price changes and their associated distributional effects has proven to be a key element in determining the social acceptability of different policies with an influence on energy prices (Zhang and Baranzini, 2004).

Regarding Spanish specifics, there has been a sustained and sizeable rise in energy consumption since the 1980s, growing external dependence and exposure to exogenous price shocks[1]. The increasing Spanish energy/GDP ratio has also provoked a poor environmental performance, especially in greenhouse gases, which are now approximately 40% higher than the 1990 Kyoto baseline (i.e. 25% over the EU bubble allocation to Spain). In this sense, household shares of total energy consumption and associated CO_2 emissions have been growing in Spain during the last few decades.

In this context, corrective and intense public policies are to be expected in the short term and thus further insight into the various effects of Spanish energy price changes seems especially necessary. In fact, tax policies are likely to play an increasingly important role in the future as Spain is well below EU average energy tax levels and they may complement other environmental policy instruments already in place. A much needed improvement in energy efficiency may be also fostered by higher prices.

Previous attempts to microsimulate energy price changes in Spain have been infrequent and incomplete, as the underlying demand system did not have a thorough disaggregation of energy goods (e.g. Labandeira and Labeaga, 1999). But even the international literature on the issue is rather limited, as most simulations have been based solely on elasticity estimates, often calculated in a single equation setting (e.g. Micklewright, 1989; Brannlund and Gren, 1999). In contrast, this study yields results with a high degree of precision, thanks to the use of a microsimulation procedure (as in, e.g., Symons, Gay and Proops, 1994; Cornwell and Creedy, 1996) and to the fact that the links among energy goods are explicitly and simultaneously taken into account.

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[1] Oil consumption showed a 40% increase in Spain between 1980 and 2002, for instance, quite far from EU averages.

Although our model is able to reproduce any type of price change, we illustrate the paper with a hypothetical increase of energy taxes to replicate a 50 Euro tax on CO_2 (carbon dioxide) emissions, which can be understood in several ways. First, that increase in energy taxes may be interpreted as an attempt to control the externality arising from those emissions (see Pearce, 2003). Second, it resembles some actual applications of carbon taxes by a number of northern European countries. And finally, the simulated event can be seen as a proxy of a moderate price shock of primary energy products.

The paper concludes that such a tax-induced price change would bring about a significant behavioural response by households, with positive environmental effects, large public receipts and significant welfare losses, with moderate distributional effects. Our results show the feasibility of the simulated policies within the Spanish economy and, if considered along with the severe energy and environmental constraints, point to straightforward normative recommendations.

The article is organized in five sections, including this introduction. Section 2 deals with the underlying energy demand model for Spain, including a brief methodological outline and the main estimation results. The following section focuses on the microsimulation of energy price changes in Spain, with a description of the methodology and data. Section 4 presents the simulated price change and the results obtained from the model. The final section is, as usual, devoted to highlighting the main conclusions of the paper and setting forth some policy implications.

2. Modelling Spanish household energy demand

There is an extensive literature analysing residential energy demand, with special interest in estimating the sensitivity of the demand for energy goods with respect to changes in prices and income[2]. The methodologies used are diverse, although it is possible to distinguish between two general approaches. On the one hand, some studies estimate the elasticity of the demand for certain energy goods based on an aggregate model for the totality of households and/or industries (e.g. Hondroyiannis, 2004; Kamerschen and

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[2] See the surveys by Dahl and Sterner (1991), Espey (1998) and Madlener (1996) for an overview of the main empirical results on this issue.

Porter, 2004; Holtedahl and Joutz, 2004). Others use microeconomic data to estimate the demand for energy goods in each household (e.g. Larsen and Nesbakken, 2004; Vaage, 2000; Puller and Greening, 1999; Baker, Blundell and Micklewright, 1989).

The demand model we use to obtain the required parameters for microsimulation is within the second group. However, most of those micro papers are econometric single equation models which are useful for analysing residential demand of electricity or petrol consumption, albeit not able to explore the rich interrelations among energy goods and other non-energy commodities[3]. To avoid this problem we use a multiple equation model, estimated from microdata of Spanish households, which is briefly described below[4].

The data comes from a combination of comprehensive microdata surveys on Spanish household expenditure, income and household characteristics: the Family Expenditure Survey (FES) for 1973-74 and 1980-81, and the Continuous Family Expenditure Survey (CFES) for the period 1985-1995, both managed by the Spanish National Institute of Statistics (INE). The FES 1973-74 includes information concerning more than 170 goods and services, whereas the FES 1980-81 provides data for more than 600 goods and services. The sample size of both sources is around 24,000 households, while our sample selection from the CFES gives information on about 26,000 households, yielding data for more than 270 goods and services. In order to make the data from the three surveys compatible we aggregate the expenditures in homogeneous goods attending to survey definitions. We use the same methodology for demographics, defining new variables containing the same household characteristics in the three surveys.

The FES are typical cross-section surveys providing information during the time span of a year, from the second quarter of 1973 (1980) to the first quarter of 1974 (1981). In contrast, the CFES is a rotating panel whose collaborating households are observed for a maximum of eight quarters. Since the timing of the data samples in the FES and CFES are annual and quarterly respectively, we estimated annual expenditures for each household in the CFES by adding up quarterly spending. Our central aim in combining the three surveys is to solve the main problem in estimating complete demand systems, which is arriving at the adequate identification of price effects. Even using data for such a

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[3] Some exceptions can be found in Nicol (2003) and Tiezzi (2004) which simultaneously analyse the demand for energy and other non-energy goods, or Kayser (2000) and Nesbakken (1999) for energy and durable goods.

[4] For more details on theoretical and empirical issues see Labandeira, Labeaga and Rodríguez (2004).

long period as 1985-95, the multicollinearity among price series does not allow for precise estimates or cross estimates of price responses for most goods. By using a suitable combination of data from 1973 to 1995, we are able to estimate long term and significant responses to price changes. Of course, this is a very important issue when the objective is simulation of policy impacts.

The model is based on the quadratic extension proposed by Banks, Blundell and Lewbel (1997) to the Almost Ideal Demand Model (Deaton and Muellbauer, 1980). Thus the model can capture the existence of different elasticities throughout the income distribution and can show whether goods are necessities or luxuries at different points along that distribution. In particular,

$$w_{iht} = \alpha_i + \sum_{j=1}^{I} \gamma_{ij} \ln p_{jt} + \beta_i \ \ln\left(x_{ht}/a_{ht}\right) + \frac{\lambda_i}{b_{ht}}\left(\ln\left(x_{ht}/a_{ht}\right)\right)^2 + u_{iht} \tag{1}$$

and we define a_{ht} and b_{ht} as

$$\ln a_{ht} = \alpha_0 + \sum_{j=1}^{I} \alpha_j \ln p_{jt} + \frac{1}{2}\sum_{j=1}^{I}\sum_{i=1}^{I} \gamma_{ij} \ln p_{it} \ln p_{jt} \tag{2}$$

$$\ln b_{ht} = \sum_{j=1}^{I} \beta_j \ln p_{jt} \tag{3}$$

where $i, j = 1, 2, \ldots I$ represent consumer goods considered by the model (electricity, gas, liquefied petroleum gas-LPG, car fuels, public transport, food and non-alcoholic drinks, other non-durable goods), w_{iht} is the participation of good *i* in total expenditure by household *h* at moment *t*. The price vector faced by households at each moment in time is $\vec{p}_t = \left(p_{1t}, \ldots, p_{It}\right)$, with x_{ht} being total expenditure on the goods modelled for each household.

For the estimated demand system to be coherent with consumer theory, we impose symmetry and zero degree homogeneity conditions. Thus the model defined by (1)-(3) is non-linear in the parameters, which complicates estimation. In addition, the infrequency problems associated with annual or quarterly spending for each household makes it necessary to take this fact into account. For instance, households which collaborate over eight quarters in CFES report on average a 10% of quarters without expenditure on gas and 17% in the case of car fuels[5]. The expected values of expenditure and consumption are the same under infrequency, although expenditure measures consumption with error. Therefore, the least squares method produces inconsistent estimates due to the existence of contemporaneous correlation between the error term and total expenditure. This is solved by instrumenting total expenditure with total income, which under separability conditions must be uncorrelated with the error term (Keen, 1986). In panel data we have instruments other than income, such as lags in total expenditure, but our combination of data to solve the lack of price variation prevents us from using this type of instrument. Still, we have the possibility of using three stage non-linear least squares, instrumenting income with all available demographics such as education, occupation, age, etc., to avoid the possible bias induced by the presence of measurement errors in non-linear models (Haussman, Newey and Powell, 1995).

In addition to prices and total expenditure, the empirical model considers several discrete and dummy variables common in the literature (e.g. Baker, McKay and Symons 1990; Labandeira and Labeaga, 1999; Nicol, 2003). They modify the intercept term of demand equations in order to include heterogeneity in the range of energy sources consumed by households. For example, the educational level of the household head (no education, primary, secondary or higher education), geographical location (rural, town, cities), ownership of the main residence, whether the head of the household is retired from work, and the number of household members by age (14 or under, older than 14). Moreover, we use a trend to control possible tendencies (technical progress or efficiency of use) in any of the expenditure groups[6]. This is not the only way of accounting for heterogeneity in consumer demand, as we can also scale income (and income squared) by some demographics. The flexibility of the income responses together with the translating effect of the socio-economic characteristics provide an adequate picture of the energy demand by Spanish households.

The results of the estimation highlighted the relationship between the place of residence and the consumption of energy goods. For example, households living in rural areas do not

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[5] We define the probability of infrequent purchases as one minus the ratio between the number of quarters with positive expenditure to the number of quarters the household collaborated in the panel database.

[6] Rural corresponds to those households living in municipalities with fewer than 10,001 inhabitants. Town corresponds to those households living in municipalities with more than 10,000 inhabitants but fewer than 50,001. In order to avoid perfect collinearity, we dropped the dummy corresponding to primary schooling and to households living in cities (municipalities with more than 50,000 inhabitants).

have access to the same energy goods as those living in large cities since, for instance, they are not usually connected to mains gas and thus need to consume LPG (mainly butane gas). At the same time, these households devote a greater proportion of their total expenditure to car fuels because they have different transport needs. There is also a relationship between household composition and consumption as, for instance, households with a retired head spend a smaller proportion on transport services (car fuels and public transport).

There are significative income effects on the consumption of natural gas, car fuels and other non-durable goods. LPG is preferred by low income households because it represents a cheap substitute for natural gas. Besides, car fuel consumption is associated to the possession of one or more vehicles, which in turn is highly correlated to the income level of the household. Moreover, we estimate long-run elasticities which capture the important effect of economic growth on car ownership between 1973 and 1995. All goods show a negative own price effect as expected from the theory: energy goods are relatively inelastic and other non-durable goods account for the more important price effects as they are not necessities. There are significative substitution effects between electricity and LPG but this not the case for natural gas. Finally, we found a complementarily relationship between food and LPG (the main energy for cooking).

3. Microsimulating changes in energy prices

3.1 Simulation methodology

The objective of this paper is to anticipate the response of different consumers to changes in the prices they pay for energy goods. The parameters for relative prices and income obtained from estimation of the demand system are essential for simulation purposes since they enable us to calculate the new expenditure shares of goods $\hat{w}_{ih}^1 = f\left(\vec{p}^1, x_h\right)$ as a function of prices and total expenditure, where the superscript (1 and 0) denotes the new and previous values of the explanatory variables,

$$\hat{w}_{ih}^1 = \sum_{j=1}^{N} \hat{\gamma}_{ij} \ln p^1{}_j + \hat{\beta}_i \ln \frac{x_h}{a\left(\vec{p}^1\right)} + \frac{\hat{\lambda}_i}{b\left(\vec{p}^1\right)} \left(\ln \frac{x_h}{a\left(\vec{p}^1\right)} \right)^2 \qquad (4)$$

This model, however, does not rightly predict the new expenditure shares and therefore correction is necessary, which can be achieved by adding up the share prediction error for each good (see Baker, McKay and Symons, 1990). The share prediction error for good *i* and household *h*, ε_{ih}, is the difference between the share of goods in the total spending of households as predicted by the model ($\hat{w}_{ih}^{0}$) and the observed participation in actual household expenditure (w_{ih}^{0}),

$$\varepsilon_{ih} = w_{ih}^{0} - \hat{w}_{ih}^{0}\left(\vec{p}^{\,0}, x_h\right) \tag{5}$$

The share prediction error includes something that could be interpreted as an observable fixed effect, that is, the part of each proportion not explained by the relative prices, the actual expenditure or the error term. It thus includes the estimated heterogeneity in demand in the sample of households (place of residence, household composition, tenure regime, etc). Therefore, the new participation of goods in total expenditure for each good *i* and household *h* is calculated as the sum of the values predicted by the estimates of the system plus the share prediction error,

$$\hat{w}_{ih}^{1} = f\left(\vec{p}^{\,1}, x_h\right) + \varepsilon_{ih} \tag{6}$$

To perform the simulations, prices paid by households in the new scenario must be defined as well. Consumer prices, p_i, are the sum of producer prices, q_i, excise duties, a_i, and value added taxes, $\left(a_i + q_i\right) t_{iVA}$,

$$p_i = \left(1 + t_{iVA}\right)\left(a_i + q_i\right) \tag{7}$$

For simulation purposes we have to estimate the equivalent *ad valorem* tax rate corresponding to excise duties, τ_i,. Thus consumer prices for each good in our model are,

$$p_i = \left(1 + t_{iVA}\right)\left(1 + \tau_i\right) q_i \tag{8}$$

where $\tau_i = \dfrac{a_i}{q_i}$

To calculate the new post-reform prices, we assume that the change in tax rates is fully transferred to consumers. Post-reform expenditure on each good is calculated by multiplying total expenditure, x_h, by the new shares estimated by the model, w_{ih}^1. With post-reform expenditure on each good and tax rates it is possible to estimate the new tax revenues for the government, rev_{ih}^1. For good *i,* this is

$$rev_{ih}^1 = (w_{ih}^1 x_h) \frac{\left(1 + t_{iVA}^1\right)\left(1 + \tau_i^1\right) - 1}{\left(1 + t_{iVA}^1\right)\left(1 + \tau_i^1\right)} \tag{9}$$

To perform a welfare analysis of tax reforms, we must specify household preferences corresponding to model equations (1)-(3). In particular, the household budget share equations in (1) are derived from the following indirect utility function (Banks, Blundell and Lewbel, 1997),

$$v_{ht}(x_{ht}, \mathbf{p}_{ht}) = \left[\frac{b_{ht}}{\ln(x_{ht}/a_{ht})} + d_{ht} \right]^{-1} \tag{10}$$

where d_{ht} is defined as

$$d_{ht} = \sum_{j=1}^{I} \lambda_j \ln p_{jt} \tag{11}$$

By inverting the indirect utility function above we obtain the equivalent income at pre-reform prices, $\hat{x}_h^0 = f\left(\vec{p}^0, u_h^1\right)$. This is the level of income (expenditure in this case) at reference prices (pre-reform in this case) required to attain the same post-reform utility level at final prices, $u_h^1 = f\left(\vec{p}^1, x_h\right)$, (see King, 1983). Therefore, it is possible to estimate a standard welfare measure such as equivalent variation (*EV*) as the difference between the budget constraint and equivalent income (expenditure in this case). Positive equivalent variations measure welfare losses following a rise in consumer prices, as they represent the amount of money that needs to be subtracted from the household in order to attain the post-reform level of utility at initial prices[7],

$$EV = x_h - \hat{x}_h^0 \tag{12}$$

Furthermore it is possible to calculate the deadweight losses (*DW*) from the tax reform, that is, the welfare losses which cannot be compensated with the revenues from the tax increase. This is done by subtracting the change in tax revenue from the equivalent variation,

$$DW = EV - \sum_{i=1}^{I} (rev_{ih}^1 - rev_{ih}^0) \tag{13}$$

3.2. Data

For simulation purposes we use 1995 annual data from the CFES. As mentioned in section 2, the CFES is a rotating panel whose collaborating households are observed for a maximum of eight quarters. The simplest approach to estimate annual expenditures for each household consists in adding up quarterly expenditure by households that collaborated during the four quarters of 1995. However, such a database would be insufficient because of the presence of some attrition bias, since there would be too few observations for some groups of households as those with residences in rural areas or more than 2 children.

A high degree of representativeness is important to estimate total expenditure or tax payments for the whole population[8]. In order to keep representativeness of households in our database for the year 1995, we should be able to use all households that collaborate in the survey. The lack of information (quarters without collaboration) from households that collaborate three or less quarters could be solved by using their average expenditure over all remaining quarters to estimate individual annual expenditures. But this procedure

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[7] That is the maximum amount of money that the household would be willing to pay in order to avoid the price change.

[8] Population values are calculated by multiplying data from each household by a representative grossing up factor provided for each household by the INE.

provokes some other important problems, as we lose information about the seasonal pattern of household expenditures, which is crucial to estimate annual expenditure on energy goods. In particular, this problem is especially significant for those households which only collaborate one or two quarters. Furthermore, the seasonal bias is enlarged by the presence of infrequency problems like those detected in our sample, e.g. with fuels for housing typically being bought twice a year[9].

Therefore, the aim of the methodology used for constructing annual data for individual households with CFES data must be twofold. First, it should be able to keep the representativeness of households as high as possible. Second, it should maintain the seasonal behaviour of household expenditures along the year. Subject to these two restrictions we selected out those households that collaborate at least one quarter of 1995 and also four consecutive quarters. As a result there are 2,900 households in the database used for simulations, representing about 92% of households in CFES for 1995. The database for simulation purposes includes, for example, households that collaborate the four quarters of 1995 and households that collaborate the last three quarters of 1994 plus the first quarter of 1995[10]. For the later we estimate the unknown expenditures in 1995 with the expenditures in 1994 corrected by the corresponding quarterly price indexes,

$$\hat{e}_{iht}^{1995} = I_{iht}^{94-95} e_{iht}^{1994} \qquad (14)$$

where $\hat{e}_{iht}^{1995}$ is the estimated expenditure in 1995 on good i by household h in quarter t, I_{iht}^{94-95} is the price index between 1994-95 for good i in quarter t as provided by INE, and e_{iht}^{1994} is the expenditure in 1994 on good i by household h in quarter t.

Table 1 shows the percentage of households that consume different combinations of energy goods for the house during the first quarter of 1995[11]. The most common combination is electricity and LPG, consumed by 70.5% of Spanish households. LPG is also simultaneously consumed with other energy goods, but in a much lower extent, such as liquid fuels, solid fuels and collective central heating. The number of households that

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[9] The same problem is reported in Baker, Blundell and Micklewright (1989). More explanations on infrequency problems in Spanish data can be found in Labandeira, Labeaga and Rodríguez (2004).

[10] The database is completed with households that collaborate the last two quarters of 1994 plus two quarters of 1995 and households that collaborate the last quarter of 1994 plus three quarters of 1995.

[11] We choose the first quarter because there are less infrequency problems on energy expenditure. Actual figures should be expected to be slightly higher.

consume both electricity and natural gas is also significant. Less important is simultaneous consumption of electricity and collective central heating, electricity and liquid/solid fossil fuels, and natural gas and LPG[12]. A small number of households simultaneously consumes LPG (most probably for cooking purposes) and collective central heating.

(Table 1, here)

When taking into account the place of residence, as in Table 2, results differ from the mean values reported in Table 1. Natural gas is mainly consumed in cities with more than 50,000 inhabitants whereas the opposite is true for solid and liquid fuels and LPG. It is almost straightforward to understand why there is almost no household consuming solid or liquid fuels and natural gas simultaneously. Collective central heating is mainly consumed in cities with more than 50,000 inhabitants and there is almost no consumption at all in towns with less than 10,000 inhabitants. Thus, size of municipality directly or indirectly affects the consumption of energy goods for the house, due to the availability of options (e.g. most households living in rural areas have no physical access to natural gas), and to the relationship between variable housing type (e.g. flats in cities vs. houses in rural areas) and the consumption of certain energy goods for the house.

(Table 2, here)

These differences in energy consumption arise not only between rural or urban municipalities but also within each group of households, as revealed by the Gini index for total expenditure and the concentration indexes for expenditure on each good[13]. The former is, as expected, quite similar between households living in different places, taking a value of 0.322 for municipalities with more than 50,000 inhabitants and 0.336 for municipalities with fewer than 10,001 inhabitants. However, there are important differences in concentration indexes for expenditure on LPG with values ranging from –0.053 for municipalities with more than 50,000 inhabitants to 0.110 for municipalities with fewer than 10,001 inhabitants. Therefore, expenditure on LPG is in general evenly distributed between households, with some extreme cases existing in cities. This means

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[12] In most cases, this indicates a transition from LPG to natural gas consumption.

[13] The Gini index and Lorenz curve measure the extent to which the distribution of income or consumption among individuals or households deviates from a perfectly equal distribution. The concentration index and

that low income households spend more on this type of energy, generally in relative terms but also in absolute values for cities. Figure 1 gives a graphical view of this phenomenon for the specific case of municipalities with more than 50,000 inhabitants.

(Figure 1, here)

We also found important differences in concentration indexes for expenditures in public transport between households living in municipalities with more than 50,000 inhabitants and those with fewer than 10,001 inhabitants (0.354 and 0.251 respectively). So the concentration curve for expenditure on public transport is under the Lorenz curve for income distribution in the former and above it in the latter, which means more inequality and less inequality respectively. Finally, there is less inequality in the expenditure on electricity and food as these items can be described as necessities, whereas the reverse is true for expenditure on car fuels and other non-durable goods.

The analysis of the data has confirmed the importance of disaggregating the consumption of different gases (LPG and natural gas) in our model. Disaggregation allows us to analyse the effects that a change in the relative prices of energy goods for the house has on the consumption of gases, in accordance with the characteristics of the household (rural vs. urban, wealthy vs. poor).

4. The effects of increasing energy taxes on Spanish households

4.1 The simulated reform

As previously mentioned, in this article we simulate the effects of the introduction of a tax on Spanish CO_2 emissions. In any case, our general objective is to illustrate the microsimulation model with a significant change in the prices of different energy goods, something which could have a different origin (increase in the taxation of energy for revenue purposes, exogenous price shock in inputs, etc.).

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concentration curve for expenditure on each individual good are basically the same but with population ordered by total expenditure.

The tax rate used for simulation effects is 50 Euros per ton of CO_2, similar to the applied in certain countries such as Sweden and Norway[14]. This is a relatively high tax rate if we compare it with those existing in other European countries, like Holland and Finland, or with the prices expected from the emissions trade market which will begin in the EU in 2005. However, we believe that its use is justified by the estimations of the social cost produced by the emissions of this gas, which situate the rate in a plausible interval[15]. In addition, the considerable deviation of Spanish CO_2 emissions from compliance with the Kyoto Protocol and the manifest inefficiencies of the energy sector make a strong corrective intervention advisable. Furthermore, the remarkable instability of the market in raw energy goods means that price shocks are very pronounced on occasions, and this is another factor that validates our choice.

To perform the simulation with the household demand model we need to know the effects that the tax under consideration will have on the prices paid by consumers. In order to calculate them, we have used an input-output model which allows us to compute the changes in the prices of all the goods consumed by the households following the simulated tax (Symons, Proops and Gay, 1994; Labandeira and Labeaga, 1999). This is because, given the strong dependence of all sectors on the energy sector, any analysis that examines the direct effects on the prices of energy goods would necessarily be incomplete.

The input-output model used makes it possible to compute the carbon content of each of the goods and services produced in the economy. We can thus calculate the direct CO_2 emissions (through the consumption of fossil fuels) as well as the indirect emissions (consumption of other goods and services) by households. The data regarding the intensity of the CO_2 emissions in each of the sectors has been taken from Labandeira and Labeaga (2002), who use 1992 as the year of reference. Unfortunately we do not have reliable disaggregated data for more recent years in Spain, although the changes in sector intensities of CO_2 are probably of little significance owing to the absence of structural changes in such a short span of time.

The price changes brought about by the environmental tax are calculated by combining the data of the input-output table for the Spanish economy in the year 1995 with the sectoral intensities of CO_2 for 1992. To do so we deflate the tax rate to 1992 prices and

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[14] See e.g. Swedish Tax Authority (2003).

[15] See recent surveys on the issue, such as Pearce (2003) or Tol (2004).

obtain the price changes as percentage increments, calculated as an adjusted average of the weight of each sector in the input-output table of 1995 on each group of goods in the household demand model.

Table 3 shows the effects of the simulated tax on the prices of each of the goods. The environmental tax causes a significant increase in the price of electricity and of the different fossil gases, also bringing about sizable but lesser increments in the price of public transport services and car fuels. This is to be expected given the reduced taxation of energy goods for the household in relation to fuels, which are already the object of a notable excise duty mainly for revenue purposes.

(Table 3, here)

4. Results

In this section we address some of the economic, distributional and environmental effects of the simulated CO_2 tax in 1995. First we look at the degree of behavioural response by households to the change in prices, and then proceed to describe the revenue effects and their distribution across goods and households. Finally we explore the welfare effects of the simulated reform in terms of welfare measures, efficiency losses and pollution correction.

Table 4 shows the changes in the expenditure by all households, as well as the changes in the demand for different groups of goods. The latter are estimated upon the basis of price changes and the monetary expenditure of the households. The rise in the cost of electricity leads to its partial substitution by LPG due to the generalised use of both types of energy for cooking and house heating. There is a notable reduction in the demand for natural gas, used mainly for house and water heating in households located in urban areas. Only reductions in the expenditure on food and other goods are observed, despite the relatively small increase in the prices of these items. The relative rigidity of the demand for energy goods for the household and for transport services, along with the increase in their prices, requires that adjustments have to be made in the expenditure on food and other goods.

(Table 4, here)

Table 5 shows the tax revenues obtained from the goods included in the demand system before and after the tax reform. It can be seen how in the pre-reform situation most tax revenues are collected from three groups: other non-durables, car fuel and food-beverages. In this sense, the high relative weight of vehicle fuel within indirect taxation has mainly to do with the high excise duties and demand rigidity. Regarding post-reform, the simulated tax increase clearly generates a significant amount of receipts, while its distribution among the various goods is rather uneven. The greatest revenue change comes from the consumption of LPG which responds not only to the increase in taxation, exceptionally low in the pre-reform situation, but also to an increase in its consumption due to the substitution effects. There is also a strong rise in the revenue obtained from electricity, where the greatest price increases occur, and public transport services. Revenues from food and non-alcoholic beverages grow more than one third, a result which could not be anticipated and which is due to the significant rise in relative terms of the taxes levied on these goods. Car fuels and other goods experience the smallest revenue increases in relative terms, although in the case of car fuels there is a significant rise in absolute public receipts as indicated above.

(Table 5, here)

A relevant matter is how the burden of those tax revenues is distributed over income groups, which can be observed in Table 6. The increase in tax payment caused by the introduction of the environmental tax is noteworthy, and ranges from an average of about 19% for households in the first decile to around 10% for those belonging to the last decile. This suggests that an environmental tax such as the simulated has a regressive effect on income distribution in Spain. The finding is obviously related to the fact that most energy goods are considered necessities (see section 3.2) and also to the interaction effects that they have on other goods such as food. Also, the relatively smaller increase in the price of fuels diminishes the potential progressive effects that could be expected from this phenomenon[16].

(Table 6, here)

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[16] See Speck (1999) for a discussion on this subject.

The results described above are coherent with those obtained by other empirical studies (Cornwell and Creedy, 1996; Symons et al, 1994; Metcalf, 1999). However, they contradict the usual argument that a tax on CO_2 emissions would have a neutral effect in Mediterranean countries (e.g. Barker and Kolher, 1998; Labandeira and Labeaga, 1999; Tiezzi, 2004). In particular, Labandeira and Labeaga (1999) stated that the distributive effects of a Spanish tax on CO_2 emissions at a lower rate tended toward proportionality. This can be explained by the smaller increases in the prices of energy goods and other goods, which could have masked the real distributive changes.

In Table 7 we show the distributive effects when we classify the households according to other variables of interest (work status, number of children under the age of 14, place of residence). The effects depicted by the table are now of little significance, the maximum difference being 1.5 percentage points. Households with a retired head and households living in rural areas are the most negatively affected. In any case, both groups of households have an average lower income and therefore energy goods have greater weight in the total expenditure. Retired persons tend to be more sedentary, moreover, which increases the consumption of energy goods for the household. At the same time, households living in rural areas depend to a greater extent on private transport and therefore consume more fuels. In sum, the income level of households is the main determinant of the distributive effects of energy price changes, above other considerations such as the place of residence or household composition.

(Table 7, here)

The simulation model also makes it possible to calculate the effects of the environmental tax on the welfare of households. Table 8 shows the absolute loss of welfare measured as an equivalent variation. The equivalent variation is also presented in relative terms compared to the total expenditure made by each household. The effects of the increased tax are certainly significant since the losses are substantial in absolute terms for each type of household. Variable distributional effects are not detected in such measurements, however, representing approximately the same expenditure proportion for each grouping of households.

Table 8 also shows the efficiency losses caused by the introduction of the simulated tax. It is evident, as anticipated by Public Economics, that the efficiency loss in relative terms rises progressively with the level of income, i.e. the simulated tax distorts more intensely the decisions of richer households. In a most extreme case, households belonging to the tenth decile, there exists an excess burden of more than two thirds of the extra tax revenue. Obviously, this is because households with less income are more dependent on the expenditure on necessities and they have fewer possibilities of substitution and/or adaptation when faced with price rises.

(Table 8, here)

Finally, Table 9 shows the environmental effects produced by the simulated reform. We have considered both the direct emissions by the households in their consumption of fossil fuels as well as the indirect emissions associated with consuming other goods and services. For the latter we have taken the emissions by each productive sector in 1995, as published in INE (2002). As a result, CO_2 emissions fall around 4% if we consider both the direct and the indirect emissions of the residential sector. There is notable substitution between electricity and LPG, so that part of the fall in the CO_2 emissions generated by the consumption of electricity is compensated by an increase in the consumption of LPG.

(Table 9, here)

Although not reported in Table 9, significant reductions are also produced in the emissions of nitrogen oxides (–4.4%) and sulphur dioxide (–7.4%). Sulphur and nitrogen oxide emissions are responsible for acid rain and adverse health effects, being mainly caused by the consumption of fuels for transport and indirectly through the consumption of electricity and some non-energy goods. Therefore, changes in energy prices contribute significantly to the reduction of different environmental problems, providing ancillary benefits and yet another reason for the introduction of corrective policies.

5. Conclusions

In this article we have presented a microsimulation model to calculate the effects of hypothetical *ex-ante* price changes in the Spanish energy domain. Our main aim was to obtain in-depth information on the behavioural responses by different types of households, which would allow us to determine the welfare effects of such price changes, their distribution across society and the environmental consequences within the residential sector. The model rests on our prior estimation of a demand system, especially designed for a simultaneous analysis of different energy goods, with Spanish household data from 1973 to 1995.

Our contribution to the empirical literature is twofold. We have largely improved previous attempts to simulate the effects of energy price changes in Spain, thus enlarging the relatively scarce international literature on the issue. Besides, we have provided precise and robust results on several effects associated to energy price rises, as we used a microsimulation procedure that focused on the energy domain and took into account the links among different energy goods.

Moreover, we believe that the context surrounding this piece of research shows the practical relevance of the article. The significance of the economic and distributional effects related to energy price changes, from both positive and normative points of view, is clearly unquestionable. As it also is the growing environmental concerns and the large inefficiencies that have surrounded the Spanish energy domain in recent years, which demand a detailed economic approach to the issue.

Although the microsimulation model is capable of reproducing any type of price change, we illustrate the paper with a simulation of the effects of an energy tax that resembles a 50 Euro tax on carbon dioxide emissions. On the one hand, this tax rate intends to approximate the externality arising from such emissions, being also close to those actually applied by some European countries. On the other hand, it can be justified by the uncontrolled path of Spanish emissions and energy consumption, being also able to replicate the effects of a large price shock affecting primary energy inputs.

The results of the simulation point to a significant behavioural response by households (as we adjust demand in the long run), sizeable emission reductions, greater tax revenues, welfare changes and moderate distributional effects. The changes in expenditures on different goods are varied and cannot be explained exclusively by the effect of the simulated tax on prices. Other relevant variables are the heterogeneity of households and the possibilities of substituting certain energy goods for others. Tax receipts from a tax on CO_2 emissions are sizeable, as it is to be expected for goods with relatively rigid demand and important tax rate increases. We have also seen how the distribution of the tax burden among the population tends toward regressivity, which is an important contribution of the paper in view of previous results for the Mediterranean countries.

The effects of the reform on households' welfare also appear to be significant in absolute terms. Unlike welfare losses, the loss of efficiency in relative terms grows progressively with the level of income, i.e. the environmental tax distorts more intensely the decisions made by households with higher income. Finally, we have shown how the environmental impact of these tax reforms is noteworthy, and they not only affect carbon dioxide emissions but also produce secondary environmental benefits.

The simulated policy seems, therefore, a feasible option for tackling some of the current and severe inefficiencies in Spanish energy and environmental fields. The observed effectiveness suggests that a more positive approach should be taken towards this policy option, largely ignored and even rejected by Spanish policy makers so far. In particular, carbon taxes may play an important role to control the emissions from sectors excluded from the European market for carbon permits, as transport and households. As shown in the paper, such an increase in the efficiency of climate change policies is simultaneous to other positive benefits in several fields, although at a certain distributional cost.

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Table 1. Combination of energies for the house in observed expenditure

	Electricity	Natural gas	LPG	Liquid fuels	Solid fuels	Collective central heating
Electricity	100.00	13.38	70.50	3.23	4.63	5.84
Natural gas		13.38	1.47	0.03	0.00	0.62
LPG			70.50	1.99	4.21	2.45
Liquid fuels				3.23	0.00	0.00
Solid fuels					4.63	0.00
Collective central heating						5.84

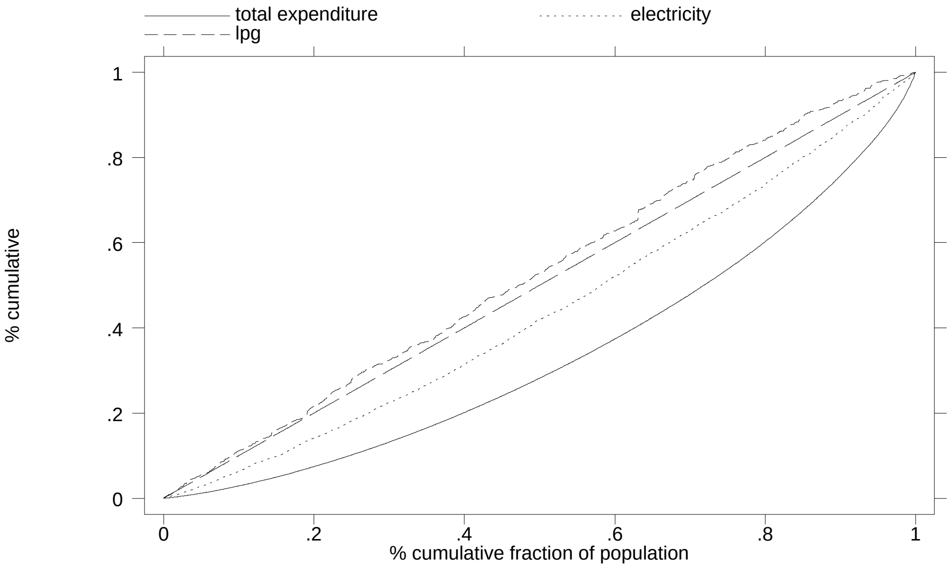
Source: Own calculations from household expenditure in the first quarter of 1995

Table 2. Population of place of residence and energy consumption in % of households

	Less than 10,001	10,001-50,000	More than 50,000
Natural gas	2.17	6.35	22.98
LPG	81.23	75.08	58.57
Liquid fuels	3.93	1.73	1.51
Solid fuels	5.42	2.03	1.63
Collective central heating	0.40	2.45	9.86

Source: Own calculations from household expenditure in the first quarter of 1995

Figure 1. Lorenz curve for total expenditure of households living in cities and Concentration curves for electricity and LPG



Source: Own calculations from household expenditure in the first quarter of 1995. Curves correspond to a Gini index of 0.321 and concentration indexes of 0.12 for electricity and -0.053 for LPG

Table 3. Simulated price changes in %

Electricity	23.66
Natural/Mains gas	15.85
LPG	17.18
Car fuels	6.39
Public transport	8.51
Food and beverages	2.35
Other non-durables	0.96

Source: Own calculations

Table 4. Per cent changes on expenditure by group of goods and demand in 1995

	Expenditure	Demand
Electricity	14.0	–7.8
Natural/mains gas	1.8	–12.1
LPG	22.9	4.8
Car fuels	2.5	–3.6
Public transport	4.2	–4.0
Food and beverages	–1.3	–3.5
Other non-durables	–0.4	–1.4

Source: Own calculations

Table 5. Tax revenue by group of goods and per cent changes in 1995

	Pre-reform (Euros)	Increase (%)
Electricity	443,071,791	151.0
Natural/mains gas	53,399,829	89.0
LPG	65,142,257	281.0
Car fuels	4,239,588,905	4.9
Public transport	136,471,568	120.3
Food and beverages	2,310,923,461	36.1
Other non-durables	16,332,842,504	5.5
Total	*23,581,440,314*	*12.8*

Source: Own calculations

Table 6. Distributional effects by decile. Average tax payments and per cent increases over pre-reform

	Euros	%
1	106.7	19.1
2	151.1	16.5
3	183.3	15.5
4	213.8	14.2
5	242.4	13.6
6	272.7	13.5
7	303.8	12.8
8	339.3	12.3
9	396.9	11.8
10	540.7	10.7

Source: Own calculations

Table 7. Distributional effects by group of taxpayers. Average tax payments and per cent increases over pre-reform

	Euros	%
Retired	223.9	13.9
No Children	260.5	12.9
2 Children	295.2	12.8
>2 Children	322.2	13.2
Rural	246.2	13.4
City	295.4	12.4
Average	*277*	*12.8*

Source: Own calculations

Table 8. Equivalent variations (EV) and deadweight losses (DW) in Euros and per cent changes over total expenditure (EV) and tax revenue (DW)

	EV		DW	
	Euros	%	**Euros**	%
Decile 1	133	2.70	26	25
Decile 2	202	2.70	51	34
Decile 3	253	2.70	70	38
Decile 4	304	2.70	90	42
Decile 5	354	2.70	112	46
Decile 6	405	2.70	132	49
Decile 7	461	2.69	157	52
Decile 8	532	2.69	193	57
Decile 9	644	2.69	247	62
Decile 10	937	2.67	396	73
Retired	334	2.68	110	49
No Children	399	2.68	138	53
2 Children	454	2.70	159	54
>2 Children	496	2.71	174	54
Rural	361	2.69	115	47
City	468	2.69	173	58

Source: Own calculations

Table 9. CO_2 emission reductions (in %) from the simulated tax

Electricity	–7.8
Natural Gas	–12.1
LPG	4.8
Car fuels	–3.6
Public transport	–4.0
Food and beverages	–3.5
Other non-durables	–1.4
Total	*–3.7*

Source: Own calculations