5. Microsimulation in the analysis of environmental tax reform. An application for Spain

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5.1. Introduction[1]

During recent decades numerous economic policies have been introduced, such as trade liberalisation or changes to the tax system; subsidies that have had important implications for the efficiency of the economy, but also for inequality, poverty and, in general, the welfare of individuals. Internationally, there has been a significant effort to improve the efficiency of the economy by reducing international trade barriers. However, the need has emerged in recent years to analyse the effects of trade liberalisation on inequality and poverty, due to the correlation between globalisation and the redistribution system (Dollard, David and Kraay 2000).

Tax reforms enacted in numerous countries since the beguining of the 1980s have represented a change in the hierarchy of taxation principles in favour of efficiency, horizontal equity and simplicity (Gago and Labandeira 2000). Recently, proposals to modify taxation of energy, or more generally, to introduce en-

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vironmental taxes have sought to attain efficiency improvements through better resource distribution. However, it is important to remember that these measures also have effects on distribution (Speck 1999).

The redistributional consequences of a specific public policy are often a fundamental factor in determining its acceptability. In many cases, law and policymakers introduce special measures to marshal political support from citizens or corporate executives. Obviously, this type of action can derail achievement of the primary efficiency objectives that should guide decision making. For example, tax deductions for non-polluting companies or homes is an option to be considered for potential environmental policies.

Currently, microeconomic models represent the most usual approach to analysing distributional aspects. Such methods require the use of microeconomic databases with containing data on individuals, households or companies. The most interesting aspect of the use of this data is that it allows the large disparity existing between economic agents to be taken into account. In the case of families, this disparity is related to their income, the actual composition of the household and its preferences. The main drawback of microsimulation models is that they exist in a setting of partial equilibrium that does not allow relative prices to be endogenised, which leads to potentially biased results. Furthermore, they are not the most appropriate framework for analysing efficiency aspects deriving from public policies. As such, a trade-off must be acknowledged between the analysis of distributional effects and efficiency, and it will be up to researchers to choose from the diversity of instruments available.

Also, applied general equilibrium models (AGEM) permit analysis of the impacts of economic policy measures, especially on the economy. Established on microeconomic fundamentals, they allow the interaction between all component sectors and institutions of the economy to be studied. AGEM are therefore a powerful instrument for analysing the efficiency and other macroeconomic effects of public policies already in place or measures that may be put into practice. Nevertheless, despite their potential they are not capable of evaluating the redistributional effects of such policies on households and therefore lack the ability to calculate welfare related aspects. This problem is common to instruments based on the existence of representative consumers or even aggregate models with a significant number of representative consumers (Bourguignon, Robilliard and Robinson 2003). Constructing households or individuals according to specific characteristics, such as occupation, income source or place of residence, constitutes a limitation in the sense that it misses out on much of the heterogeneity existing between households belonging to these standard groups.

In this study, we propose a methodology to evaluate the redistributional and efficiency effects of public policies without losing the heterogeneity between homes provided by the surveys. We have therefore created a model at microeconomic level for the purposes of adjusting the demand for household energy. We integrate this model via prices with an AGEM. The AGEM allows us to understand changes brought about by a given social welfare policy, and to identify the relative prices and levels of sector and institutional activity. We can then integrate the results into a microeconomic model in order to unbundle the effects of that policy on the welfare of sample households and, if appropriate, to aggregate the results at the level of the reference population.

In order to illustrate how the simulation instrument works, we propose to evaluate the effects of a tax reform that consists of raising indirect taxes on coal, electricity, hydrocarbons and natural gas by 20%. The reform and its timing can be justified as follows:

— There are initiatives at EU level to control greenhouse gases following the ratification of the Kyoto protocol in April 2002;[2]
— This is a typical measure that will have an impact on both efficiency and the distribution of income (Bovenberg and Goulder 2002). The extra tax revenue obtained from the increase will be used to reduce indirect taxes on other goods so as to achieve a zero net tax impact in real terms. The results of these tax changes suggest an improvement in the levels

[2] For example, the European coal market in 2005 or the tax harmonisation of energy goods in the EU.

> of sector activity and, therefore, the activity of the Spanish economy as a whole. They do not, however, produce significant changes in the prices of capital and labour. Therefore, all the redistributional effects occur via changes in the prices of goods and services. In this way we find significant distributional effects, which in our opinion justifies the obtention of integrated models for the global analysis of the potential effects of public policies.

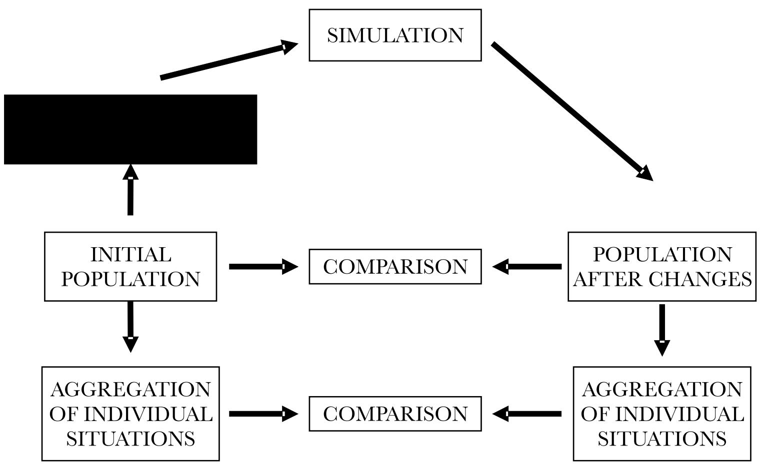
The analysis contains four sections apart from the introduction. In section 5.2 we attempt to explain why it is desirable, on some occasions, to integrate micro and macro economic models, and we review the available empirical evidence. Section 5.3 explains how the two instruments that comprise the model work. Section 5.4 presents the policies that we want to simulate and analyses the results. Section 5.5 establishes a series of conclusions and makes some economic policy recommendations.

5.2. Methods of integrating micro and macroeconomic models

If we follow the reasoning of the previous section, it is logical to think that the integration of micro and macro models will give us the benefit of both methodologies. Both procedures are complementary since AGEM does not offer the differentiation that microsimulation models provide (generally microeconometric models) and microsimulation instruments do not have the characteristics of the AGEM (Aaberge, Colombino, Holmoy, Strom and Wennemo 2004).

The simplest integration procedure consists of adding macroeconomic aspects to a microeconomic model, but without constructing an AGEM. This can be done, for example, by combining a microsimulation instrument with an input-output table. Nevertheless, decisions about the content of the individual instruments must be made in advance. What form should the microeconomic model have? We could consider purely arithmetic models but also dynamic models, meaning those that incorporate agent behaviour. Figure 5.1 illustrates both possibilities, which are differentiated by the ability to include (or not) an econometric model, or more specifically, a microeconometric model. Arithmetical models do not measure agent reactions; they calculate the morning-after effect. Dynamic models need to be adjusted for behaviour, which is done by using econometric methods with the objective of endogenising (and explaining) the decisions of individuals in relation to their labour supply, demand, seasonal consumption or savings. Alternatively, the relevant parameters (usually elasticities) may be taken from the empirical literature in order to include them in the simulation routines. Of the numerous applications for the simple integration of a microeconomic model with an input-output table, we would highlight two studies applying to Spain by Manresa and Sancho (1997) and Labandeira and Labeaga (1999). Despite the methodological improvement obtained in comparison with a simple adjusted microeconomic model, at least two difficulties persist: i) it creates a model in a partial equilibrium framework; ii) the input-output methods are static and do not include potential responses from the sectors and/or institutions.

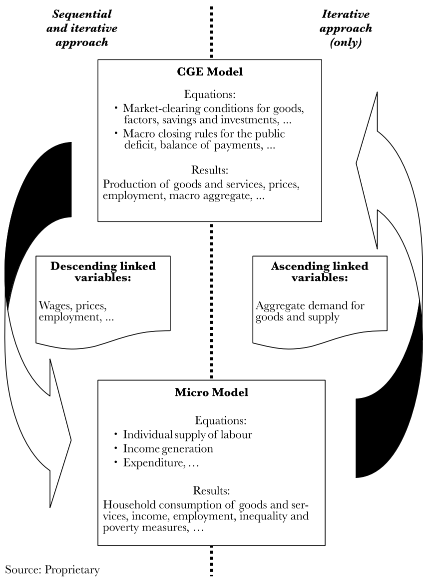
FIGURE 5.1: Structure of a microsimulation model



Source: Proprietary

The next step, from a methodological perspective, is to construct an instrument that integrates microsimulation models and AGEM. There are at least two strategies that we can use, which differ in the degree of integration achieved. The simplest method is to use a sequential procedure, as in Bourguignon, Robilliard and Robinson (2003). For the purposes of their exercise, they use an AGEM with ten representative consumers, which gives the effects of macroeconomic shocks on poverty and inequalities in Indonesia. The microeconometric model takes the changes in relative prices from the AGEM, in addition to other macroeconomic variables, which enter as exogenous factors, as shown in figure 5.2.

FIGURE 5.2: Sequential and iterative AGEM and microeconomic model integration procedures



Source: Proprietary

The principal advantage of sequential integration is that it provides information about the impact on household welfare at a microeconomic level, allowing the model to maintain a high degree of flexibility. Nevertheless, there is still the problem of guaranteeing the consistency between both instruments. Note that this consistency cannot always be guaranteed unless we include feedback effects between both instruments. In this respect, Savard (2003) proposes an innovation on the methodology of Bourguignon, Robilliard and Robinson (2003), which allows two-way relations between the microeconomic model and the AGEM, forcing consistent solutions to be obtained between both through the convergence of final results. The behaviour of households is accordingly fixed when the AGEM simulations are carried out. The results of these simulations are an input for the microeconometric model (or for the simulation instrument), which allows the effects of reform at a microeconomic level to be calculated. Once responses from the households obtained via the micro model are available, information is used as an input to the AGEM providing new values for the variables previously considered as exogenous (figure 5.2). The procedure does not end with this stage but follows an iterative process until convergence is achieved in the results provided by both instruments.

For our purposes, what interests most about the Bourguignon, Robilliard and Robinson (2003) proposal is the possibility of comparing results obtained under various scenarios, first using the simulation instruments individually and then using the integrated model. These authors find highly significant differences, not only in the magnitude of the changes but also in their sign. Savard (2003) also provides very different results between the two procedures as regards distribution and poverty aspects, in an exercise which simulates a trade policy reform in the Philippines.

5.3. Details of the integrated micro-macro model

This section is wholly dedicated to describing the procedure we use in this paper. Its fundamental methodological contribution is to evaluate the effects of a tax reform influencing energy goods on the efficiency of economic sectors (and the overall efficiency of the economy) and its consequences for individual welfare. The empirical exercise integrates an AGEM specifically designed to simulate environmental taxation policies impacting energy taxes on the basis of household demand behaviour vis-à-vis the diverse energy sources available. We therefore use a top-down procedure in order to study the macroeconomic effects of policies and a bottom-up method to analyse their distributional effects. Similarly to Bourguignon, Robilliard and Robinson (2003), we take the changes in prices and income provided by the AGEM as exogenous variables in order to carry out simulations using the demand model (or the microsimulation instrument). Bearing in mind this operation, we first calculate the relative prices for each good using the AGEM $P_{inew}^{AGEM} / P_{ibase}^{AGEM}$. The new relative prices resulting from the reform, P_{inew}^{MIC} , that will be used as an input to the microsimulation instrument are calculated by multiplying the pre-reform prices, P_{ibase}^{MIC} , by the percentage changes in the corresponding variables derived from the AGEM:

$$P_{inew}^{MIC} = (P_{inew}^{AGEM} / P_{ibase}^{AGEM}) P_{ibase}^{MIC}$$

As a result, integration between both modules occurs sequentially. We are interested in analysing potential policies with a sector-based impact on the supply and demand for goods and services, with minimal effects on income. In relation to income, the only simulation we conduct relates to the expenditure of each household, leaving aside the income generation process at an aggregate level. Given the assumed effects that reforms will have on income, the sequential method used is not a significant problem for conclusions compared to the iterative alternative.

A primary objective of our analysis is to obtain complete information with the highest possible degree of differentiation on welfare and distribution effects of changes in taxation. Inconsistencies can certainly occur between survey data and aggregate data. The objectives behind constructing both data sources do not prevent these problems occurring, either in the data sources for Spain or for other countries. Although the samples from the Continuous Family Budget Survey (ECPF), which is the base used in the analysis, are representative of the population, the sampling processes are not entirely successful in minimising the impact of these problems. Since the ECPF provides factors for elevating the survey data to population level, we use these factors to obtain aggregate figures, which we collate with the figures from Spanish National Accounts (Symons, Proops and Gay, 1994 or Bourguignon, Robilliard and Robinson 2003).

5.3.1. The Applied General Equilibrium Model[3]

In order to evaluate the efficiency effects of energy and environmental policies, we use a static AGEM whose structure is described below. First, sectors and institutions will be separated out as much as available information allows. This disaggregation is important insofar as we wish to factor energy consumption's heterogeneity. It is especially important in the case of the energy sector for the purposes of this exercise, since this sector provides different intermediate inputs for production (electrical services, heating, transport services, etc.) and these inputs exhibit important differences in relation to CO_2 emission factors.[4] We should not forget that the effectiveness of environmental policies and their cost efficiency depend on two key factors: the price of the energy required to conserve the environment and the substitution between energy sources (from dirty to clean energies, depending on the emission factors).

The 17 production sectors in the model produce with constant returns to scale and minimise costs in competitive contexts. The production function, which is specifically designed to accommodate environmental policies, is a succession of constant elasticity of substitution functions (CES), as shown in figure 5.A.1.[5] As is normal in AGEM models, the total production for sector i arises from combining intermediate inputs and a good composed of labour, capital and various sources of energy using a Leontief technique.

We use the Armington method to model international trans-

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[3] The notation criterion conforms to the following convention: endogenous variables are expressed in capital letters and exogenous variables in capital letters with a line over the letter.

[4] CO2 emission factors in Spain are: 98kg/GJ for coal; 73kg/GJ for refined petroleum products and 55kg/GJ for natural gas.

[5] The AGEM used incorporates various modifications in relation to the AGEM used by Böhringer, Ferris and Rutherford (1997), although in essence it is the same model.

actions in goods. Imported and domestic goods are imperfect substitutes in terms of production. The total supply of goods and services from the economy is therefore a combination obtained from different sources using CES functions. The maximisation of profits by each sector, which is determined via a constant elasticity transformation function, distributes the supply of goods and services between domestic consumption and the foreign market.[6] Since our case is a small economy and most of Spain's trade in goods is with EU countries, the exchange rate is fixed (in fact, most foreign trade is with Eurozone countries) and agents face exogenous prices from the rest of the world.[7]

The supply of capital is inelastic (distributed exogenously between institutions) and has perfect mobility between sectors, but it is not allowed to be mobile internationally. Households offer labour so that they maximise their utility. Labour is also mobile between sectors, although not internationally.

The public sector collects direct taxes (personal income tax from households and also taxes on sector wages) and indirect taxes (on production and consumption). The provision of capital from the government (K_G), transfers to other institutions (TR_G) and the public deficit (DP) are exogenous variables. The consumption of government goods and services (D_{iG}) is determined via a Cobb Douglas type function in which PD_i are domestic prices. A balance must therefore exist between total public expenditure, capital income and tax revenue (REV) that fulfils the following budgetary restriction:

$$\overline{DP} = r \cdot \overline{K}_G + \overline{TR}_G + REV - \sum_{i=1}^{17} PD_i \cdot D_{Gi} \qquad (5.1)$$

in which r is the price of capital services.

The representative household has a fixed amount of time that

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[6] For a detailed description of the treatment of international trade in AGEM, see Shoven and Whalley (1992).

[7] We will assume that the policies simulated have no significant impact on the euro exchange rate, given that the countries that trade most with Spain belong to the Monetary Union and therefore any impact on the Spanish economy will be relatively limited.

it divides between leisure (*LS*) and work. It maximises utility (*W*) which is a function of leisure and of a good comprising remaining goods and savings (*UA*), subject to the budgetary constraint.[8]

$$W = \left(s_{UB} LS^{\frac{\sigma^{UB}-1}{\sigma^{UB}}} + (1 - s_{UB}) UA^{\frac{\sigma^{UB}-1}{\sigma^{UB}}} \right)^{\frac{\sigma^{UB}}{\sigma^{UB}-1}} \tag{5.2}$$

We assume, as do Böhringer and Rutherford (1997), that consumers have a marginal propensity to save based on their disposable income (Y_H). Disposable income comprises income from capital, salaries (W is the nominal salary and SC_H are social contributions) and transfers, an amount from which income tax must be subtracted (T_H is the tax rate). The consumption of goods and services is defined by a structure of nested CES functions, as shown in figure 5.A.2, which focuses especially on the demand for energy goods. An important contribution of the AGEM is the distinction between energy for household uses, energy for private transport and other energy products.[9]

$$Y_H = (1 - T_H)\left[r \cdot \overline{K}_H + w(1 - SC_H) \cdot \overline{(TIME} - LS) + \overline{TR}_H \right] \tag{5.3}$$

The AGEM is a model structure based on the Walrasian equilibrium concept. This means that for any simulated policy the model finds a set of market-clearing prices and quantities (of goods, labour and capital).[10] The total saving for the economy (*SAVINGS*) is defined endogenously and is equal to the sum of savings generated by all institutions. The macroeconomic equilibrium of the model continues to be defined by the exogenous capacity/requirement of the economy to finance/be financed by the foreign sector (*CAPNEC*). This capacity/requirement arises

[8] σ^{UB} is the elasticity of substitution and S_{UB} is the proportion that leisure represents in welfare.

[9] This distinction is common in microeconomic models. Other non-energy goods are a composite good for which a Cobb-Douglas formula is also chosen.

[10] There are no quantity adjustments in the supply of capital from the economy because the capital stock of all institutions is an exogenous variable. The only changes occur in the use of capital by the production sectors. The equilibrium condition is obtained from changes in the price of capital services (r).

from the difference between national savings, the public deficit and internal investment, which are aggregated via a Leontief function of the different goods used in gross capital formation, INV_i:

$$SAVINGS + \overline{DP} - \sum_{i=1}^{17} PD_i \cdot INV_i = \overline{CAPNEC} \tag{5.4}$$

International prices PXM_i, transfers between the foreign sector and other institutions and the consumption of goods and services by foreign residents in Spain (D_{iRM}) are considered exogenous variables. Exports (EXP_i) and imports (IMP_i) must therefore satisfy the restriction faced by the foreign sector:

$$\sum_{i=1}^{17} \overline{PXM}_i \cdot EXP_i + \overline{TR}_{RM} + CNR - \sum_{i=1}^{17} \overline{PXM}_i \cdot IMP_i = \overline{CAPNEC} \text{ where } CNR = \sum_{i=1}^{17} PD_i \cdot \overline{D}_{iRM} \tag{5.5}$$

The model is also capable of simulating CO_2 emissions from different energy sources. Emissions are generated only during production processes which use fossil fuels. There is therefore a technological relationship between the consumption of fossil fuels in physical units and emissions, whose parameters for coal, refined petroleum products and natural gas are θ_C, θ_R and θ_G respectively. For example, given the technology, the corresponding CO_2 emissions for sector i will be:

$$CO_{2i} = q_{Ci}\, COAL_i + q_{Ri}\, REF_i + GAS_i \tag{5.6}$$

5.3.2. Model data and calibration

To analyse the effects of public policies using the instrument described, it is essential to construct in advance a National Accounts Matrix (NAM-95) for the Spanish economy. We base our own on the National Accounts for 1995.[11] We also extend the available database with environmental data relating fossil fuel consumption and emissions for each production sector and insti-

[11] The NAM-95 that we use is based on a NAM published by Fernández and Manrique (2004). For a more detailed description of the procedure see Rodríguez (2003). The 1995 Spanish National Accounts follow the European System of Accounts (ESA-95).

tution considered. Unfortunately, there is no source that provides data to the required level of detail. Therefore, we had to estimate environmental data using diverse sources such as the Andalusian Statistics Institute (IEA) (1998) or the Spanish Statistics Institute (INE) (2002a, 2002b).

Using the information obtained from the NAM-95, some model parameters such as tax rates, technical production and consumption coefficients and the parameters of the utility function are obtained through calibration. As is common knowledge, the criterion for calibrating the model is that the AGEM replicates the NAM-95 information as an equilibrium, which is used as a starting point, and in our case as the benchmark with which to compare the results of the simulations.[12]

Other model parameters are taken from the literature as an alternative to calibrating them. For example, hours supply elasticity to wages is set at 0.4, similar to that obtained by Labeaga and Sanz (2001). In running the simulation for the initial situation, we follow the procedure used by Ballard, Shoven and Whalley (1985) to obtain the elasticity of labour supply and assume that leisure represents a third of the available hours (Parry, Williams and Goulder 1999). In all cases, since this elasticity value is central to the result obtained, sensitivity analysis has been carried out, increasing and decreasing this value by 50 percent. From this analysis we can conclude that the results provided by the AGEM are robust at different elasticity values.

5.3.3. A microeconomic model for household energy demand

In order to evaluate the distributional effects of implementing environmental policy measures (of a fiscal nature), we use a system of demand for energy goods with household data (Labandeira, Labeaga and Rodríguez 2005). This section describes the most important characteristics of the model and presents the principal results. The theoretical model underpinning econometric estimation is the quadratic extension of the

[12] For a brief description of the methodology, see Shoven and Whalley (1992). The AGEM was programmed in GAMS/MPSGE. The method proposed by Rutherford (1999) is used for the calibration, employing the PATH algorithm.

Almost Ideal Demand System of Deaton and Muellbauer (1980) proposed by Banks, Blundell and Lewbel (1997). The demand system adjusts the proportions of expenditure on each good in relation to the total amount that each household spends on non-durable goods, based on the prices of the goods, total expenditure and total expenditure squared, apart from demographic characteristics:

$$w_{iht} = a_i + \sum_{j=1}^{n} g_{ij} \log p_{jt} + b_i \log \frac{x_{ht}}{a(p_t)} + \frac{l_i}{b(p_t)} \left[\log \frac{x_{ht}}{a(p_t)} \right]^2 \quad (5.7)$$

$$\log a(p_t) = a_0 + \sum_{i=1}^{n} a_i \log p_{it} + \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} g_{ij} \log p_{it} \log p_{jt} \quad (5.8)$$

$$b(p_t) = \prod_{i=1}^{n} p_{it}^{b_i} \quad (5.9)$$

in which the goods of the system are denoted by i, j = 1, 2,…n (electricity, natural gas, LPGs—propane and, mainly, butane—fuel for private transport, public transport, food and non-alcoholic beverages and other non-durable goods); w_{iht} is the proportion of good i in the total expenditure of household h at time t; p_{it} is the price of good i at time t; and x_{ht} is the total household expenditure on non-durable goods in real terms at time t (deflated by a Stone price index).

The distinction between different energy sources consumed in the home is crucial (Baker, Blundell and Micklewright 1989). Electricity provides households with numerous services such as artificial light, cold for conserving foodstuffs, cooking, cleaning or heating. Conversely, coal, natural gas or refined petroleum products provide services that are more limited and even of a different type (mainly, heating and transport services). We therefore estimate the complete demand system for all the goods listed, and do it simultaneously since we have to input the theoretical zero degree homogeneity restrictions for prices and income and symmetry in order to have a system that is consistent with consumer theory and to be able to use it for the purposes of subsequent welfare and distribution evaluations.

Among the demographic characteristics that influence demand for the goods considered, we include fictitious variables for the level of education of the head of the household, the geographic location of the household and ownership of the home, as well as variables that control family composition by age and a trend with which we seek to control patterns over time in the distribution of expenses, which in the case of energy sources can take into account technical advances that improve the efficiency of energy producing devices.

The data we use originate from a combination of microeconomic data sources containing information on household spending, income and demographic characteristics. Specifically, we combine the Family Budget Survey from 1973-74 and 1980-81 and the Continuous Family Budget Survey (ECPF) for the 1985-1995 period. All these surveys were carried out by the Spanish Statistics Institute (INE). The 1973-74 Family Budget Survey provides information on more than 170 goods, while the 1980-81 survey contains more than 600 goods and services. The sample size of both is approximately 24,000 homes. The ECPF sample that we use has information on 26,000 homes and more than 270 goods and services. To make the three data sources compatible, we aggregate the goods into standardized groups according to the definitions given in the surveys. To construct demographic variables, we use the same definitions in the three surveys in order to produce the same variables.

Our decision to combine these three surveys responds to a primary objective. In general, it is hard to identify price effects when estimating complete demand systems. This is due to the limited variation between them and the high collinearity between the price series of different goods. Our experience is that even when the system is estimated for a relatively long period such as 1985-95, the multi-collinearity in the price series does not allow for precise estimates of either the price coefficients or the cross effects. But combining data for a time-period such as that covered by the three surveys (1973-1995) allows us to adequately identify the price responses. The obvious disadvantage of such a long period is that we have to assume no changes in demand patterns for Spanish households or else take this fact into account when estimating the system. Moreover, if the objective is to use the estimated parameters to simulate tax measures affecting the price of goods, then estimating the effects accurately is of key importance.

The results of system estimates show the importance of adjusting consumer behaviour using microeconomic data. Differences also in the demand for goods need to be taken into account, such as access to energy sources like natural gas that are available to urban households but not to households in rural areas. Other goods like public transport are also harder to access in rural areas. Therefore, households in rural areas have to move around by private vehicle with the resulting purchase of hydrocarbons, while those in urban areas can substitute private for public transport services when relative prices change. The results of the model also demonstrate the importance of household composition in the consumption of goods, since, for example, households of retired people spend less on transport services because they can use subsidised public services in place of private ones.

We can identify significant income effects on the consumption of the goods making up the system. Among energy sources, LPG is preferred by lowincome households because it represents a cheap substitute for natural gas. Furthermore, the use of petrol or diesel for vehicles is associated with the ownership of one or more vehicles, which is a decision correlated to household income. The price elasticity of all goods forming part of the system is negative, as required by the theory. Energy goods are relatively inelastic while price elasticity for the group of other non-durable goods is much more pronounced.[13]

We use the same methodology as Baker, Blundell and Micklewright (1989) and Labeaga and López (1994) to carry out the simulations, which are run with annual data for 1995 taken from the Continuous Family Budget Survey. The procedure used

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[13] For further information about the construction and description of the database and the results, consult Labandeira, Labeaga and Rodríguez (2005). More details on the microsimulation model are given in Labandeira, Labeaga and Rodríguez (2004).

allows changes in demand, tax payments and welfare measures to be obtained. In this study, we provide equivalent variations following the procedure described in Banks, Blundell and Lewbel (1997).

5.4. Results obtained via the integrated micro-macro model

5.4.1. Description of the reform

In this study we analyse the effects of a green tax reform consisting of a 20% increase in the indirect taxes charged on the consumption of energy goods: electricity, refined petroleum products, natural gas and coal. The revenues generated are used to finance a general reduction in VAT rates (except on the aforementioned energy goods). The objective of the reform is therefore to increase taxation on energy goods while the public budget remains unchanged in real terms.

The reason behind the reform relates to the relatively low taxation of energy products in Spain compared to other EU members. The European Commission has made frequent proposals to harmonise taxation on energy products, although to date it has not achieved any meaningful agreement. An additional objective of the reform is to contribute to the control over Spanish greenhouse gas emissions (GHG). The EU has ratified the Kyoto protocol, which establishes an 8% reduction in European GHG by 2010 based on emissions from 1990. The rule for distributing this reduction among EU members resulted in Spain being permitted to increase its emissions by 15% during the same period. But by the end of 2002, they had increased by more than 35%.

5.4.2. Results

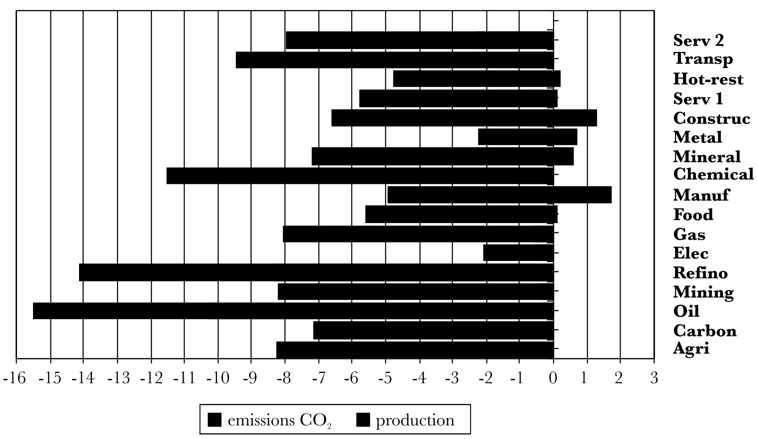
The green tax reform produces a positive effect on economic activity, increasing GDP by 1%. Demand for labour remains unchanged and there are no significant effects on wage levels and capital returns in real terms.[14] The effects of reform on main mac-

[14] Prices relative to the CPI.

roeconomic variables are therefore insignificant, generally speaking, despite their increased differentiation at the sector level, which we demonstrate below. As a result, the changes undergone in goods and services and the consumption disparity of households are the only sources of the reform's distributional effects.

Figure 5.3 shows the effects of tax reform on activity and CO_2 emissions in each sector. In terms of activity, production of refined petroleum products (REFINO) is most negatively affected, decreasing by 8%.[15] This is because tax paid on these products is very high, up to nearly 200% in the case of petrol. A 20% increase in tax rates therefore has a significant effect on their prices. However, the reform has a limited effect on the prices of electricity (ELEC) and natural gas (GAS), as shown in table 5.1. Both these circumstances encourage the substitution of refined petroleum products. As a result the impact of the reform on electricity production and natural gas distribution is of little significance (0.5% decrease).

FIGURE 5.3: Changes in production and emissions by sector (%)



A significant finding among non-energy sectors is the negative impact on certain services such as leisure, culture, educa-

[15] The impact is greater still on oil and natural gas extraction, but the activity of this sector in Spain is insignificant.

tion or healthcare (SERV2). These are sectors with a relatively low pre-reform taxation which therefore benefit little from the reduction in indirect taxation. Activity in the transport services (TRANSP) and chemicals (CHEMICAL) sectors also decreased, both of them highly dependent on the consumption of refined petroleum products. Nevertheless, tax reform is capable of generating significant improvements in certain sectors, encouraged by the reduction in indirect taxes. Some manufacturing sectors (MANUF) and the construction sector (CONSTRUC) are positively impacted, with approximate increases of 1.5%, while activity in mineral product (MINERAL) and metal (METAL) sectors increases by 0.7%.

The 20% hike in tax rates on the consumption of certain energy goods allows Spanish CO_2 emissions to be reduced by 5.7%. Its distribution across sectors is highly unequal, as shown by figure 5.3. On the one hand, the oil refining, chemical products and transport services sectors decline by more than 9%, while the electrical and mineral products sectors fall by a modest 2%. We should not forget that nuclear and hydroelectric power stations account for more than half of Spain's electricity production.

Table 5.1 shows the percentage changes in relative post-reform prices, which will be introduced as an input into the household energy demand model. The reform causes a significant increase (23.35%) in fuel prices, although the effects on remaining energy goods are much less. This is due to the relatively modest tax on these goods (16% on electricity or natural gas and 7% on LPGs). Changes in energy goods prices produce a small increase in the price of public transport services (1.4%) and decreases in the prices of food and other goods (0.83% and 1.09% respectively). This latter finding will have important consequences for the reform's distribution effects.

Changes in households' average expenditure on each of these goods are also collated in table 5.1. The largest increase occurs in fuels (17.6%); a lower amount than the increase in fuel prices, indicating a fall in consumption. The increase in electricity prices compared to gas encourages some substitution between household energies. Expenditure on electricity falls by 6.5% while that on gas moves up by more than 10%. Expenditure on private transport services, foodstuffs and other goods also falls. We must therefore conclude that the significant increase in fuel prices combined with the low response from consumers (a relatively inelastic good) are compensated by reductions in the consumption of other goods (public transport services, food). In reality, changes in the consumption of food and other goods are not that significant considering the changes in their prices and in average expenditure (negative and positive effects respectively).

TABLE 5.1: Percentage changes in relative prices and average expenditure

	Prices	Av. expenditure
Electricity	2.79	–6.49
Natural gas	1.70	11.21
LPG	1.00	16.40
Fuels	23.35	17.60
Public transport	1.40	–2.50
Foodstuffs and beverages	–0.83	–1.72
Other, non-durable	–1.09	–0.73

Note: Changes in prices in relation to the CPI. Changes in expenditure correspond to average values for all households in the sample.
Source: Proprietary.

The reform has a significant impact on household welfare, as illustrated by table 5.2, where we show equivalent variations in welfare measured in euros and in relative terms versus total expenditure in each income group (population is divided into deciles).[16] In general, an improvement is found equivalent to more than 1% in terms of total expenditure. This is reasonable considering that total expenditure on energy goods (higher tax rates) represents less than 10% of overall total expenditure for the majority of households. Data from the table also show

[16] We calculate the equivalent variations in welfare using the methodology proposed in Banks, Blundell and Lewbel (1997).

that the reform has progressive effects on income distribution. Households in the first decile improve their welfare by 2.06% in terms of total expenditure, while households in the last decile improve by only 1.26%. As would be expected, households with fewer vehicles and therefore lower fuel consumption (the poorest) benefit most from the reform.

TABLE 5.2: **Distributional effects of tax reform. Equivalent variations per decile and percentages in relation to total expenditure**

Decile	Euros	%
1st	101	2.06
2nd	141	1.89
3rd	166	1.80
4th	189	1.70
5th	210	1.60
6th	235	1.56
7th	260	1.5
8th	290	1.47
9th	332	1.39
10th	442	1.26

Note: Average values for households in each decile
Source: Proprietary.

Alternatively, households can be classified according to diverse variables such as employment status of the head of household, number of children (minors) or the location of the home, as shown in table 5.3. The results in distributional terms are less significant in this case, compared to an income-based classification. The households that benefit the least from the reform are those with multiple children under the age of 15 and residents in urban areas (towns with more than 50,000 inhabitants). The results obtained for both groups of families are a product of the positive relationship between the number of children or the location of the home and the level of income. In rural households, higher dependence on private transport (fuel expenditure) is offset by the lower level of average income (greater weight of food expenditure and less vehicle ownership). Households that benefit the most are those where the head of the family is retired and therefore have less income and consume less fuel. We conclude from these results that the distributional effects of reform are closely tied to household income level.

TABLE 5.3: Distributional effects of the reform on household groups

Household type	Euros	%
Retired	223	1.80
Without children	234	1.57
2 children	233	1.38
4 children	244	1.33
Rural	211	1.57
Urban	257	1.47

Note: Average values of the equivalent variation for households in each group
Source: Proprietary.

Finally, the results given in table 5.4 show that an increase of 20% in tax rates on electricity, gas and fuel consumption combined with a reduction in VAT on the consumption of remaining goods generates significant environmental effects. The microeconomic energy demand model estimates that Spanish households would reduce their CO_2 emissions by 2.32%. Furthermore, the tax reform would reduce their sulphur dioxide (SO_2) emissions, the gas responsible for acid rain by 8.65% and reduce nitrous oxide emissions (NO_x), which cause significant health problems and acid rain by 5.5%.

TABLE 5.4: Environmental effects of the reform. Changes in household emissions (%)

	CO_2	SO_2	NO_x
Electricity	– 9.03%	– 9.03%	– 9.03%
Natural gas	9.36%		
LPG	15.25%		
Fuels	– 4.66%	– 4.66%	– 4.66%
Public transport	– 3.84%		

TABLE 5.4 *(cont.)*: **Environmental effects of the reform. Changes in household emissions** (%)

	CO_2	SO_2	NO_x
Foodstuffs and beverages	– 0.89%		
Others, non–durable	0.36%		
Total	**– 2.32%**	**– 8.65%**	**– 5.50%**

Source: Proprietary.

5.5. Conclusions

Public policies that pursue economic improvements in terms of efficiency tend to cause secondary positive or negative effects on income distribution. However, the analytical methodologies used to study both effects are different. General equilibrium methods are the most appropriate for analysing the efficiency of public policies. But when they include a representative household no distributional analysis can be carried out. More disaggregated models can also produce incorrect results according to the empirical evidence in the literature. Microeconomic models are appropriate for distribution analysis but not efficiency analysis, due to their partial equilibrium approach.

In this paper, we used a new methodological approach integrating different analytical methods to study the effects of public policies. In particular, we integrate a static general equilibrium model which allows us to evaluate the effects of a reform on the efficiency and activity of economic sectors, with a household energy microeconomic demand model that allows us to disaggregate results by different types of household. To illustrate the suitability of the proposed methodology, we simulate a policy consisting of a 20% tax increase on the consumption of different energy goods. The tax revenues obtained are used to finance a reduction in the tax charge on remaining goods and services in the economy, the objective being a zero public budget impact.

Our results indicate that reform contributes to significantly reducing pollutant emissions. It also provides other benefits apart from environmental ones, such as a modest increase in production. As expected, the effects of the reform are markedly unequal by sector. While overall production increases, production in energy intensive sectors falls. The effects on prices also vary by sector, with significant increases in the prices of energy intensive sectors and modest price reductions in goods that form a more important part of the household shopping basket. Since no significant changes in income are detected, price changes and household heterogeneity are the only sources for changes in income distribution.

The distributional consequences for some homes are significant. In general, there is a welfare improvement that which impacts redistributional aspects. On average, the ratio between the equivalent variation and total expenditure is greater than 1% for all households. This figure is 63 percent higher for the poorest households (first decile in the distribution) than for the richest (last decile). Following tax reform, households where the principal earner is retired also benefit more than the average. This result is interesting because most evidence available at international level suggests that taxes on energy goods are regressive, although this evidence is generally obtained from partial equilibrium models. However, in Spain and other Mediterranean countries, in one context or another, energy taxes, in the worst of cases, have a very low level of regressivity.

The study also has some methodological implications. It shows that analysis can be significantly improved by integrating different methods. The AGEM allows for richer and more detailed studies on the macroeconomic effects of public policies. Integrated with a microsimulation model at the household or individual level, it fills out results to the greatest possible heterogeneity, allowing welfare analysis to be carried out at individual level.

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Appendix. Production and consumption structures

FIGURE 5.A.1. Structure of the production technology of companies

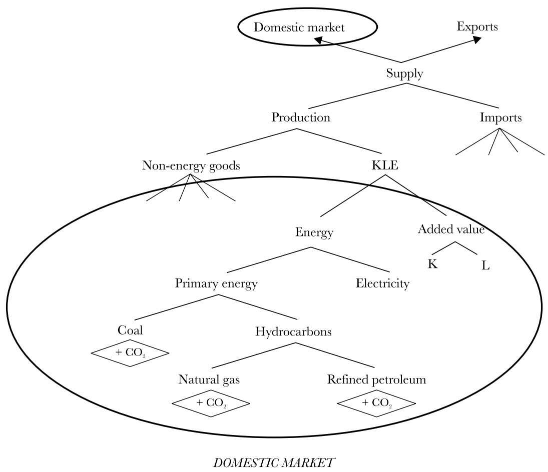

FIGURE 5.A.2. Structure of household consumption decisions

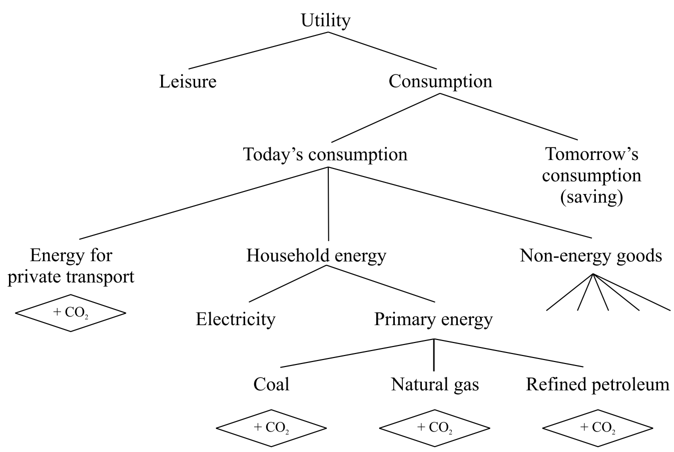

TABLE 5.A.1: Branches of activity and their MCS-1995 and TSIO-1995 relationship

MCN-95 sectors	Description	TSIO 1995 Code
AGRI	Agriculture, livestock and game, forestry, fisheries and aquaculture	TSIO 01, 02, 03
CARBON	Extraction and agglomeration of anthracite, coal, lignite and peat	TSIO 04
CRUDO	Extraction of crude oil and natural gas. Extraction of uranium and thorium minerals	TSIO 05
MINER	Extraction of metallic, non-metallic and non-energy minerals	TSIO 06, 07
PETROL	Coke plants, oil refining and nuclear fuel treatments	TSIO 08
ELEC	Electricity	TSIO 09
GAS NAT	Natural gas	TSIO 10
ALIM	Food and beverages	TSIO 12-15
MANUF	Other manufactured products	TSIO 11, 16-20, 31-38
QUIMIO	Industrial chemicals	TSIO 21-24
PROMIN	Other manufactured non-metallic minerals, recycling	TSIO 25-28, 39
METAL	Metals processing, metal products	TSIO 29, 30
CONS	Construction	TSIO 40
SERV1	Telecommunications, financial services, real estate, leasing, information technology, R&D, professional services, business associations	TSIO 41-43, 50-58, 71
HOST	Hospitality	TSIO 44
TRANSP	Transport services	TSIO 45-49
SERV2	Education, healthcare, veterinary and social services, sanitation, leisure, culture, sports, public administrations	TSIO 59-70

Note: 1. The Symmetrical Input Output Table (TSIO) codes represent the different branches of activity in the TSIO published by Spanish Statistics Institute INE (2002a).
Source: Proprietary.