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Cost-effectiveness and incidence of alternative mechanisms for financing renewables

Xaquin Garcia-Muros [a*], Christoph Böhringer[b] and Mikel Gonzalez-Eguino[a]

The promotion of renewable energy in the electricity sector is increasing rapidly around the world based on its positive environmental and socioeconomic effects. However, there is also growing concern about the effect that these policies may have on the final price of electricity and how this may affect different social groups and competitiveness. Here we study distributional implications of different schemes for financing the promotion of renewables in the Spanish electricity sector. These schemes include exemptions from the electricity surcharge for residential and industry consumers and also various alternatives where the cost of renewables is not financed through the electricity bill but from other tax sources such as oil taxes, value added taxes or lump-sum transfers. The method that we use is an integration of a computable general equilibrium (CGE) model and a microsimulation (MS) model that enables us to capture a rich representation of the heterogeneity of households along with inter-sectoral and price-related effects, which are fundamental for analyzing the implications of schemes that are not restricted to the electricity sector. Our results provide evidence against using an electricity surcharge to finance the promotion of renewables due to its regressive effects. However, alternative financing options that do not increase electricity prices can significantly attenuate these adverse effects while not affecting welfare or competitiveness.

Keywords: promotion of renewable, alternative financing options, regressive effects, macroeconomic impacts.

JEL Classification: H23, Q4, Q58.

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1. Introduction

Promoting renewable energy has become a policy priority for governments around the world[1] because of its positive environmental and socioeconomic effects, such those related to climate change, energy security, “green" jobs, public health, and energy access. In this context, renewable energy deployment is increasing fast[2] (IEA, 2016) and in 2015 investments in renewable power capacity accounted for more than half of the new global installed capacity for the first time (FS-UNEP, 2016). In the European Union (UE-28), for example, the share of electricity produced with renewable sources (RES-E) grew from 14.4 % in 2004 to 27.5 % in 2014 (Eurostat, 2016), mainly due to the rapid expansion of wind and solar technologies in countries such as Germany or Spain. It is expected to increase more in the future to achieve the energy and climate targets adopted for 2030 and 2050 (EC, 2011, 2014).

However, there is also concern about the potential effect of promoting RES-E on the final price of electricity and how this may affect different social groups, firms and competitiveness. Although renewables are already economically competitive in various circumstances and their cost has decreased drastically in recent years[3] (IEA, 2016), their average levelized private[4] costs are higher than those of conventional sources (IPCC, 2011), especially when the costs of the network infrastructures and the back-up systems needed to cover for the intermittency of renewables are considered. The main instrument[5] for supporting renewables has been technology-specific feed-in tariffs (FITs) in the electricity sector, a mechanism that guarantees a long-term fixed price for RES-E and an obligation to purchase all output from renewable sources. The difference between FITs and the wholesale[6] electricity price is accounted for as subsides to renewables, and included in the retail electricity price as a surcharge on renewables. In the EU, for example, the price of electricity increased from 2005 to 2015 by 21 % for households and by 32 % for industrial consumers (Eurostat, 2016). Although the contribution of support for RES-E to the final electricity prices is still under debate (Traber and Kemfert, 2009; del Rio et al., 2016), it is clear that increases in the price of electricity undermine the social acceptability and political feasibility of policies in support of renewables. Therefore, the issue of the incidence of RES-E promotion and how to finance these schemes to offset its negative impact is now receiving increasing attention among researchers and policymakers (Schmalensee, 2012; Neuhoff et al., 2013; del Río and Mir-Artigues, 2014; Mir-Artigues et al., 2015).

1: See IRENA (2016) for a more detailed overview of the arguments used to support the promotion of renewables. More critical analyses can be found in Böhringer et al. (2007) and Fischer and Preonas. (2010).

2: The share of RES-E (wind, solar, biomass, geothermal and tide) grew from 1.3 % in 1990 to 6.7 % in 2015 (IEA, 2016).

3: The cost of solar photovoltaic (PV) energy decreased in five years (2009–2014) by 80 % and that of wind turbines by 30 % (IEA, 2016).

4: Including the monetary value of the external costs of energy would improve the competitiveness of renewable options.

5: There are other mechanisms for supporting RES-E (del Río and Mir-Artigues., 2014) but they all tend to entail passing on the promotion of renewables to the electricity bill. Other support schemes include feed-in premiums (FIPs), a price premium paid on top of the market price of electricity, and renewable portfolio standards (RPS) a quantity-based instrument that enables generators to issue RES-E certificates that electricity distributors need to surrender as a share of their annual consumption.

6: RES-E technologies have low or close to zero marginal costs which can reduce the wholesale electricity prices due to the so-called merit of order effect (Sáenz de Miera et al., 2008; Sensfuss et al., 2008; Gelabert et al., 2011). This effect depends on the relative slopes of the supply of renewable and non-renewable technologies (Fischer, 2010).

The literature on this incidence shows (Fullerton, 2008) that climate and energy policies tend to be regressive as they raise the price of fossil-fuel-intensive products, which typically represent a higher fraction of the expenditure of low-income groups (consumption channel). Also, non-fossil fuel options are usually more capital intensive than fossil fuel options so they induce firms to demand more capital relative to labor, lowering relative wages and negatively affecting low-income groups (income channel). This general finding can also be applied to the promotion of RES. Using household micro data from Germany, Neuhoff et al. (2013) show that the burden of an RES-E surcharge is significantly higher on low-income groups. They therefore propose three measures to reduce this effect: reducing the tax on electricity, increasing support for energy efficiency measures and increasing social transfers to low income groups. Using a microsimulation and a computable general equilibrium model, Böhringer et al. (2016) show the cost-efficiency losses and regressiveness of RES-E policies in Germany but also show that these effects can be decreased if exemptions to the electricity surcharge are introduced or, alternatively, if the cost of renewables is financed through other tax sources such as value added taxes (VAT).

In this paper, we apply a computable general equilibrium (CGE) model in combination with a microsimulation (MS) model to examine the distributional implications of different schemes for financing the promotion of renewables in the Spanish electricity sector. These schemes include exemptions from the RES-E surcharge on the price of electricity for residential and industry consumers, and also different alternatives where the cost to renewables is not passed on to consumers in the electricity bill, but financed by other tax sources in the energy sector, such as fuel tax, or in the overall economy, such as VAT or transfers. Our integrated modeling approach includes a rich representation of household heterogeneity and the inter-sectoral and price-related effects, which are fundamental for analyzing those implications of these schemes that are not restricted to the electricity sector.

Spain provides a relevant case study for two reasons: first, it implemented one of the strongest support schemes for renewable energy in the world through FITs that substantially increased the share of renewables in the electricity sector; and second, it had to reduce them substantially in 2013 due to concerns about their financial implications in the context of a fiscal consolidation process of the government budget in the aftermath of the Great Recession of 2008.

The rest of this paper is organized as follows. Section 2 provides an overview of the case study of Spain. Section 3 summarizes the basic structure and parameterization of the CGE and MS models used for the simulation analysis and outlines how the models are linked. Section 4 sets out the policy scenarios and discusses simulation results. Section 5 concludes.

2. RES-E promotion and electricity prices in Spain

The promotion of renewable energy in Spain has been driven historically by the main objective of increasing the share of renewables given the country's high level of dependency on imported fossil fuels. More recently, these policies have also begun to be directed at the objective of reducing greenhouse gas emissions (GHG), closely aligned with the European Union's climate and energy targets. Spain is making clear progress[7] towards the binding national target of having renewable energy account for 20 % of gross final energy consumption by 2020 and RES-E promotion policies are contributing substantially to that objective. The share of RES-E

7: The share of renewable energy in gross final energy consumption increased from 12 % in 2005 to 17 % in 2015.

in Spain doubled in ten years from 20.3 % in 2004 to 40.9 % in 2014[8] (Eurostat, 2016), due to the large-scale expansion of wind[9] and solar capacity.

The RES-E support scheme in Spain has been based mainly on feed-in tariffs and premiums since 1998, with some rather minor reforms of the whole scheme taking place in 2004 and 2007 under the Spanish Renewable Energy Act. In 2013, this system was replaced by a return-based remuneration system in which renewable operators are guaranteed a rate of return that is based on 10-year Spanish government bonds plus a spread, which was set originally at 300 basis points. The reform was motivated by the need to balance the costs and revenues of the electricity system, as cost was increasing much faster than revenues, and by 2012 there was a tariff deficit of €26 billion (equivalent to 2.5 % of GDP). The cost of support for RES-E was an important component of the regulated cost of electricity, as Figure 1 shows. The cost of promoting RES-E increased from €2.9 billion in 2005 to €6.6 billion in 2015. RES-E support costs were high partly because investments in renewables far exceeded[9] those planned by the National Energy Plan for 2015–2020: the targets envisaged total public spending of €5 billion on RES-S for the whole period but that amount was actually spent in 2010 alone. Only after 2012 did the RES-E cost and the tariff deficit start to decrease.

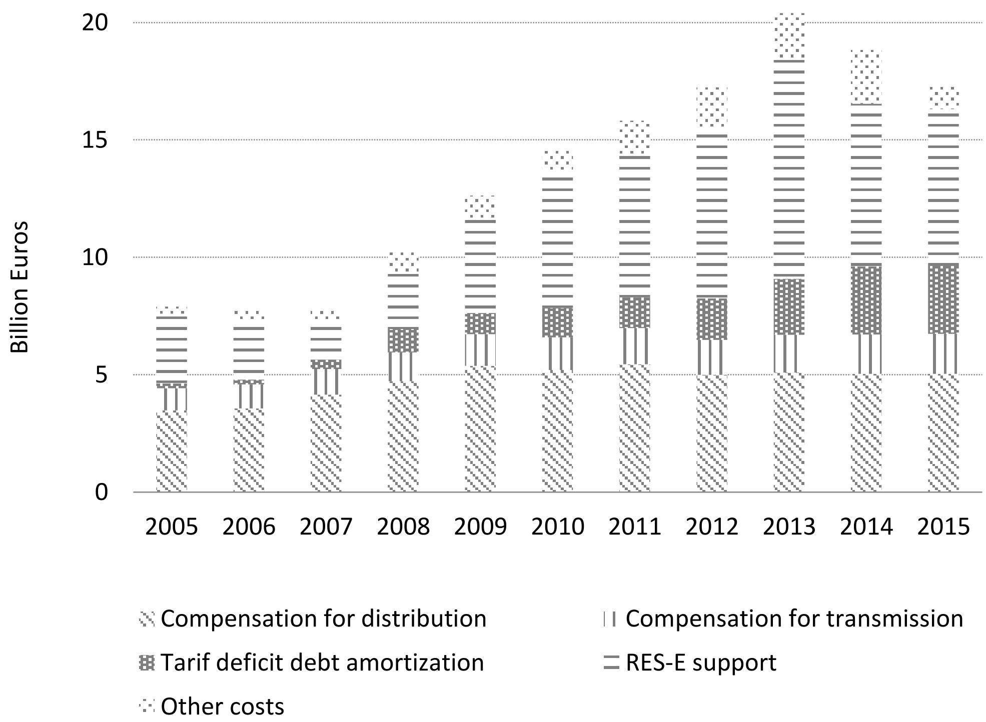

Figure 1: Regulated cost in the Spanish electricity system, 2005–2015.

8: In 2014 nuclear power was the main source of electricity generation with a share of 20.9 %, followed closely by wind power with 19.1 % and natural gas with 17.2 %. The remainder consists of coal (16.3 %), hydropower (14.3 %), oil (5.2 %), solar (5 %) and biofuels and waste (2 %). The maximum level of generation from RES-E was on 13 February 2016, when renewables accounted for 67.5 % of the day's output.

9: This was particularly the case of solar PV, which experienced an unprecedented investment spike. Solar PV generation capacity increased from 146 MW in 2006 to 3398 MW in 2008 and accounted for 56 % of all the support received by renewables despite providing just 12 % of Spain´s renewable electricity (Mir-Artigues et al., 2015).

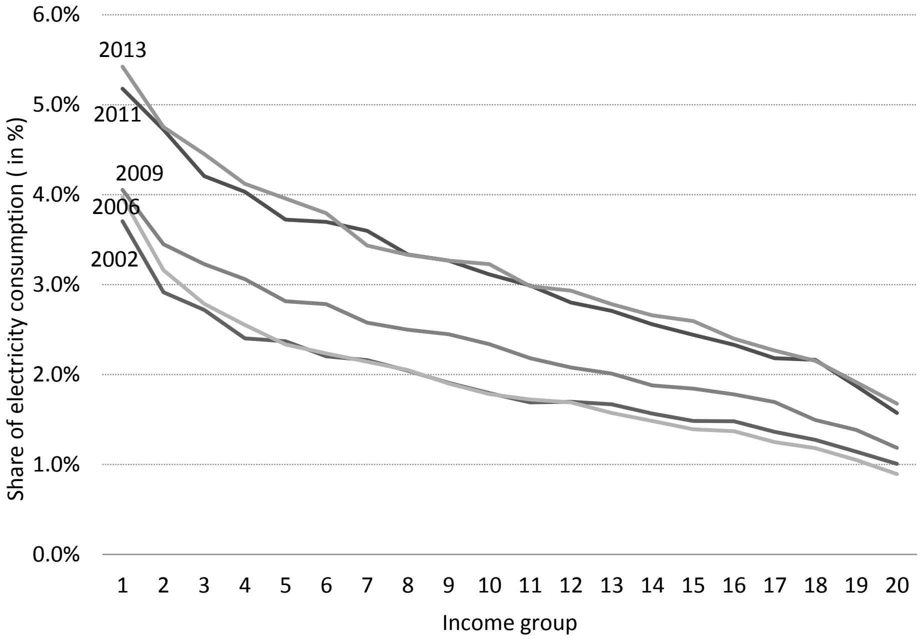

Figure 2: Percentage of total expenditure devoted to electricity per income group and year. Source: Own work with data from Spanish HBS.

In this context, electricity prices in Spain have increased significantly. The annual average electricity price for households increased from 2004 to 2014 by 109 % (from €0.1079 per kWh to €0.2252 per kWh) and for medium-sized industry by 120 % (from €0.0538 to €0.1185 per kWh). This price rise has increased spending on electricity, especially for low-income households. Figure 2 shows electricity costs as percentages of consumer spending for twenty income groups (ventiles) for various years, using data from the Spanish Income and Expenditure Survey. Spending on electricity as a proportion of disposable income increased in lowest income group (first ventile) from 4 % in 2006 to 5.5 % in 2013 and in the highest income group (twentieth ventile) from 1 % to 1.5 % for the same period. This increase reflects the increase in electricity prices but also a decline in real incomes for this period due to the economic crisis.

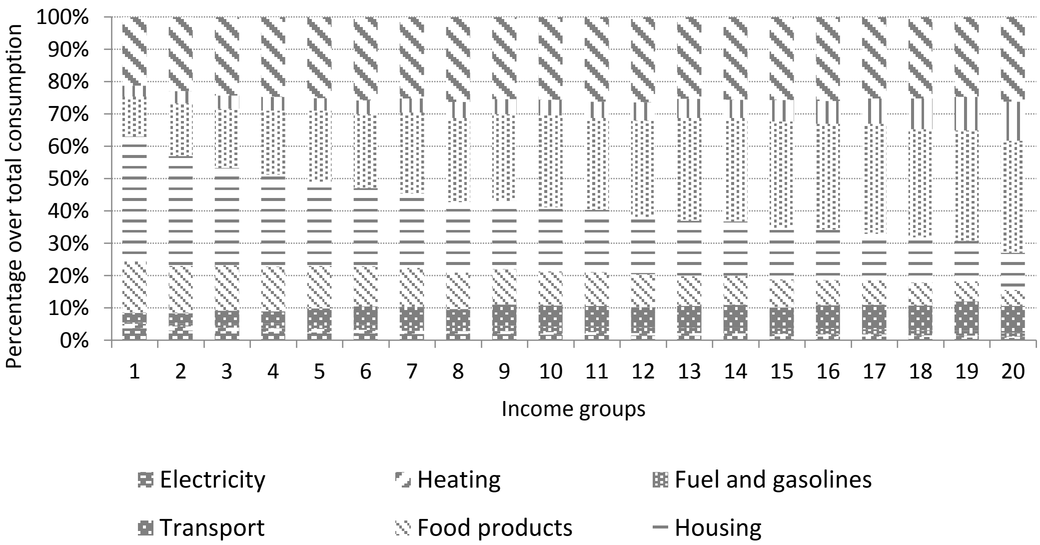

Figure 3a: Consumption patterns by income group.

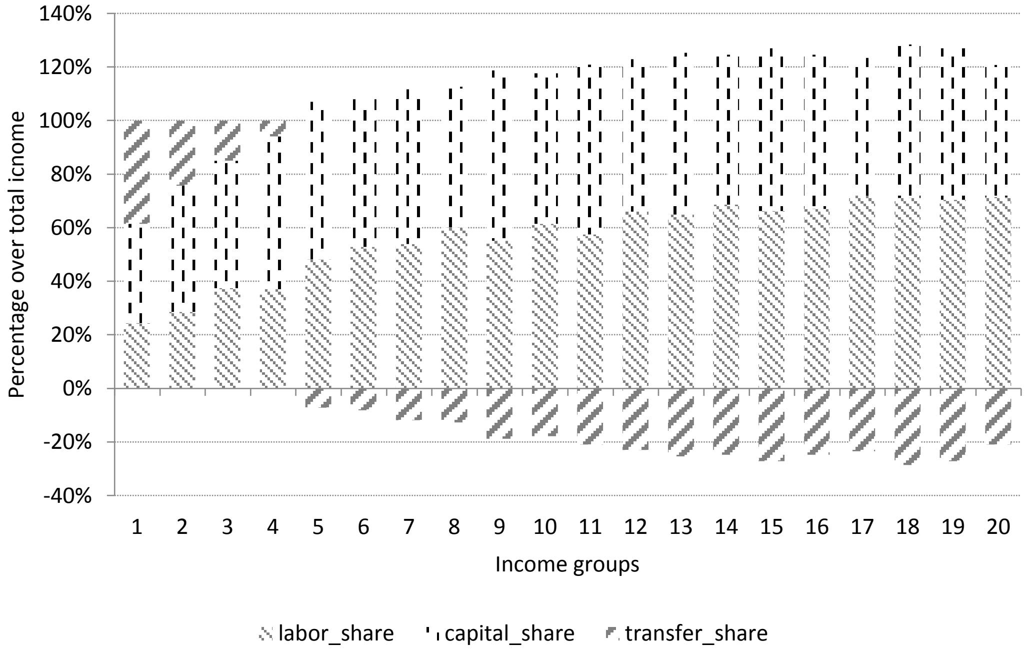

Figure 3b: Income sources by income group.

Expenditure on electricity is an important fraction of total expenditure on energy, which also includes other components such as expenditure on fuel and gasoline for private transport (ranging between 0.6 % and 1.2 % for the lowest and highest income groups) and in gas for heating (between 1.3 % and 0.5 %), as shown in Figure 3a. The structure of expenditure by social groups together and by income sources (see Figure 3b) is important information for understanding the distributional implications (consumption and the income channel) of the alternative scenarios for RES-E promotion to be assessed in this study, which are presented in the following sections.

3. Methodology and data

3.1 Methods

This paper seeks to shed further light on the relative performance of alternative financing measures for RES-E promotion. To that end, we set out a computable general equilibrium model (CGE) and a micro-simulation (MS) model for Spain. The link between CGE and MS models enables us to analyze macroeconomic policy simulations at the microeconomic level. We use a hard link approach that links the micro and macro models using a recursive or iterative process that enables us to capture feedbacks between the two models.

3.1.1 Summary of the Computable General equilibrium model.

We use a multi-sectoral CGE model to capture the economy-wide assessment of RES-E promotion. For a detailed algebraic formulation of the core model and recent application, see Böhringer et al. (2016).

Production of commodities other than fossil fuels is captured by constant elasticity of substitution (CES) cost functions describing the price-dependent use of capital, labor, energy, and material in production. At the top level, a CES composite of intermediate material demands trades off with an aggregate of energy, capital, and labor. At the second level, a CES function describes the possibilities of substitution between intermediate demand for the energy aggregate and a value-added composite of labor and capital. Finally, at the third level, a CES function captures the possibilities of capital and labor substitution within the value-added composite, while different energy inputs (coal, gas, oil, and electricity) enter the energy composite subject to a CES. In the production of fossil fuels all inputs except the sector-specific fossil fuel resource are aggregated in fixed proportions; this aggregate trades off with the sector-specific fossil fuel resource at a CES.

Final demand for consumption is determined by a representative household, which maximizes utility subject to a budget constraint with fixed investment and exogenous government provision of public goods and services. The representative agent receives income from three primary factors: labor, capital, and fossil fuel resources (coal, gas and crude oil). Labor and capital are mobile across sectors. Fossil-fuel resources are fixed to the respective resource production sectors. Final demand for consumption is given as a CES aggregate of composite non-energy consumption and composite energy consumption. Both the non-energy consumption composite and the energy consumption composite are in themselves CES functions of disaggregate non-energy and energy commodities.

Given the paramount importance of the electricity sector with respect to the promotion of renewable power generation, we break power generation down into two composite production technologies: conventional power generation and renewable power generation. These two power generation technologies produce electricity by combining technology-specific capital with inputs from labor, fuel, and materials. Electricity from different technologies is treated as a homogeneous good. Power generation technologies respond to changes in electricity prices according to technology-specific supply elasticities (for details on calibration see Rutherford 2002).

Bilateral trade follows the Armington (1969) approach of product heterogeneity, where domestic and foreign goods are distinguished by their origins. A balance of payment constraint incorporates the base-year trade deficit or surplus. All goods used on the domestic market in intermediate and final demand correspond to a CES (Armington, 1969) composite that combines domestically produced goods and the goods imported from other regions.

The model links carbon dioxide (CO_2) emissions in fixed proportions to the combustion of fossil fuels with fuel-specific CO_2 coefficients. Emission intensity or energy intensity within a sector can be reduced in two ways: by inter-fuel switching or by substituting away from fuels to non-fuel inputs. The cost of reducing intensity thus depends on the substitution elasticities and benchmark production cost shares. Total domestic emissions and energy use can also be reduced by structural shifts in production and consumption patterns.

3.1.2 Demand Model

A demand model captures the real behavior of households and provides a realistic picture of the substitution effects using econometric techniques. We estimate a demand model to provide a set of estimates of the substitution, own-price and expenditure elasticities of the goods analyzed. Accordingly, we use the well-known Almost Ideal Demand System (AIDS) proposed by Deaton and Muellbauer (1980). Its main advantage is that it enables a first-order approximation to be made to an unknown demand system. In addition, the model satisfies the economic consumption theory axioms and does not impose constraints on the utility function. The log-linear approximation (LAIDS) used in this paper follows an n-good system equation as follows:

$$W_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} ln\, p_j + \beta_i ln \left({}^{Y}/_{\tilde{p}} \right) + t + d + e_i \ , \quad [1]$$

where W_i represents the share associated with good *i* for a particular household, α_i is a constant (i.e. the consumption that is not affected by the rest of the parameters), γ_{ij} is the relationship between consumption and the price of goods, p_j is the price of commodity j, β_i is the relationship between income and consumption, $\tilde{p}$ stands for the Stone price index, Y is household income (hence, $Y/\tilde{p}$ represents real income), and t is a trend variable according with each year. Furthermore, d is a set of dummy variables that controls: the type of household[10], the region where the household is located in terms of NUTS 1, whether the household is in property, the number of rooms, the age of the breadwinner, whether the breadwinner is unemployed or retired, the number of active members in the household, whether the house is equipped with heating, and the type of house[11]. Finally, e_i is the idiosyncratic error term. The adding up and homogeneity restrictions of equation [1] are the following:

$$\sum_{i=1}^{n} \alpha_i = 1 \ , \quad [2]$$

$$\sum_{j=1}^{n} \gamma_{ij} = 0 \ , \quad [3]$$

$$\sum_{i=1}^{n} \beta_i = 0 \ . \quad [4]$$

The symmetry condition is given by:

$$\gamma_{ij} = \gamma_{ji} \ . \quad [5]$$

Finally, the sum of W_i should also satisfy the following:

$$\sum_{\mathrm{i}=1}^{n} \mathrm{w_i} = 1 \ . \quad [6]$$

In this paper we use a set of 9 consumption categories including food, housing, durables, heat, electricity, fuel, transport, leisure and education, and other products. Since the AIDS model is made up of a system of dependent equations, the share equation regarding other products is deleted to overcome singularity problems (Annex A reports the regression results).

3.1.3 Model linking

The link between CGE and MS models enables us to analyze macroeconomic policy simulations at the microeconomic level. We use a hard link, which is a recursive approach with an iterative process that enables us to include feedbacks between the two models. We follow the decomposition method used by Rutherford and Tarr (2008). This recursive approach (illustrated in Figure 4) is subdivided into three different steps. First, we solve the CGE model for the new equilibrium in the representative agent model. Second, the price and income outputs from the CGE model are used as an input in the MS to recalibrate the preferences of the representative consumer. Third, we solve the CGE model again using the new preferences of the representative agent model calibrated using the MS. This last step creates a new imbalance in markets for consumer goods. Subsequent iterations involve carrying out the first step to the third until the

10: The household categories used are the following: adults alone; couple without children; couple with children; single-parent households, and other households.

11: The house categories used are the following: luxury, high class in urban area, middle class in urban area, low class in urban area, rural industrial, rural fishing and rural agriculture.

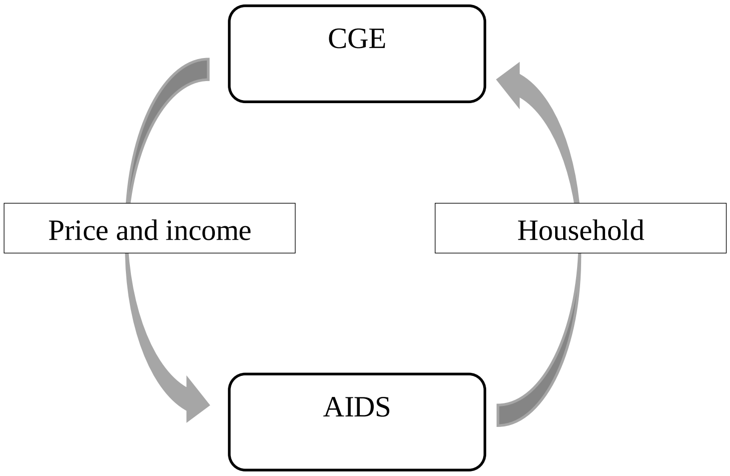

Figure 4: Recursive approach to link CGE and MS models.

two models converge; see Rausch and Rutherford (2007) or Rutherford and Tar (2008) for the detailed description of the model recalibration.

In order to implement our integrated model, we need to rescale expenditure and demand data to ensure consistency between Input–Output (IO) data and microsimulation data. To achieve the required match, we scale up the total expenditures of households from the microsimulation data to match total household expenditure according to national accounts. Similarly, on the income side, we also scale capital and labor income from the MS model to match total income according to the IO table. Due to a lack of information on savings in the survey, we decided to distribute saving decisions among households in proportion to their capital income. Finally, government transfers are equivalent to the residual between the income factor and savings.

3.2 Data

The CGE model is calibrated against the Spanish Input–Output Table for 2007 (INE, 2016a). The IO table is a representation of the uses and resources of the production sectors of the Spanish production system. Output per production sector is linked to consumption by private households in terms of consumption expenditure categories using the so-called "Z-matrix", created by the IPTS Joint Research Centre (Arto et al., 2012). The electricity sector is broken down into two power generation technologies: conventional electricity and electricity from renewables, according to technology-specific production shares provided by Eurostat (2016). Measures for the carbon emission per production sector and fossil source are obtained from the WIOD database (Genty et al., 2012). At the sectoral level, we identify primary and secondary energy carriers (coal, gas, crude oil, refined oil products, and electricity) which are essential for distinguishing energy goods by CO_2 and energy content as well by their degree of inter-fuel substitutability.

The elasticities of substitution used in the CGE are based on empirical estimates by Koesler and Schymura (2015). The elasticities of substitution in fossil fuel sectors are calibrated to match exogenous estimates of fossil fuel supply elasticities (Graham et al., 1999; Krichene, 2002; Ringlund et al., 2008). The price elasticities of electricity supply per technology are calibrated to match the changes in power generation shares across technologies following the subsidies for renewables over the period between 2007 and 2015.

For the Microsimulation model, the dataset used is from the Spanish Household Budget Survey (SHBS) (INE, 2016b). The SHBS is a representative cross-sectional survey of the whole Spanish population that collects yearly information on consumption patterns as well as socio-economic characteristics. It covers around 20,000 households per year. In the estimation stage, we use SHBS data for 2006 to 2013. In the estimation of equation [1], household expenditure is used as a proxy of income, firstly because income is strongly under-reported in household panel surveys (see for example Wadud et al., 2009) and secondly because household expenditure is a good proxy for permanent income (Poterba, 1990). The income sources of households are completed by the Living Conditions Survey[12].

Table 1: Model sectors and commodities.

Sectors	
Agriculture (Agr)	Gas and distribution (Gas)
Mining (Min)	Manufacturing (Man)
Coal (Coa)	Energy intensity (Ein)
Crude oil and gas (cru)	Services (Ser)
Petroleum products (Oil)	Transport (Trans)
Power electricity sector (Ele)	
Commodities	
Food products (Food)	Housing (House)
Transport (Tran)	Education and leisure (E&L)
Electricity (Elec)	Durables goods (Dura)
Heating (Heat)	Other goods and services (Oth)
Diesel and gasoline (Fuel)	

4. Results and discussion

4.1 Scenarios

Our research interest is in assessing the distributional impact of different schemes for financing the promotion of RES-E. The scenarios implemented in this study seek to capture two main ways of financing that promotion: i) through a surcharge on electricity prices; and ii) through an increase in other tax sources (Table 2).

Table 2: Summary of policy scenarios (scenario acronyms in parentheses).

Surcharge on electricity prices	**Alternative financing measures:**
Electricity surcharge *(BaU)*	Value added taxes (*vat*)
Electricity surcharge with an exemption on all producers *(exe_prod)*	Oil taxes (*fueltax*)
Electricity surcharge with an exemption on all households *(exe_house)*	Lump sum (*lsm*)

The main channel for supporting renewables is a surcharge on the price of electricity for both producers and households (the *BaU* scenario). However, distributional impacts also depend on how the surcharge is shared between them. Therefore, we propose two scenarios that

12: We use a proxy method to match the information from the two surveys see Rutherfor and Tarr (2008).

include exemptions from the surcharge for renewables on the price of electricity for households (*exe_house*) and for production sectors (*exe_prod*). These scenarios are two extreme situations where we explore the consequences of exemptions on either all producers or all households.

Alternatively, we also explore options where the cost of renewables is financed by increasing other taxes. The three scenarios analyzed in this study are an increase in i) valued added tax (*vat*); ii) oil taxes in the energy sector (*fueltax*); and iii) lump-sum transfers to consumers (*lsm*). These options have been proposed recently by different institutions. For example, the Spanish employers' organization, CEOE, has proposed that electricity costs not related to the cost of supply should be financed from other tax sources (CEOE, 2014). The International Energy Agency (IEA, 2015) has also recommended to the Spanish government to maintain a strong long-term commitment to balancing costs and revenues in the electricity system, and has pointed out that oil taxation in Spain is quite low; e.g. the tax component on the total diesel price is only 51 %, whereas in the United Kingdom it is 67 %, and in Italy it is 62 % (IEA, 2015).

4.2 Cost effectiveness results

This sub-section presents the overall economic effects of the different scenarios in terms of percentage point changes from the business-as-usual scenario (*BaU*), considering that each scenario achieves a similar supply of renewables.

Table 3 shows the cost-effectiveness of each scenario. The results show that the macroeconomic effects of the different scenarios are quite low. These results are not surprising, not only because each scenario uses similar revenues to finance the promotion of RES-E but also because the amounts are not highly significant compared to the total output of the economy or to GDP. However, they show that efficiency concerns alone would not provide a strong reason to deviate from financing the promotion of RES-E by increasing electricity prices. From a policy perspective, policy-makers may choose between the different financing designs without efficiency concerns.

Although the overall economic results for each scenario with respect to *BaU* are quite low, there are some differences which deserve to be highlighted. As expected, lump sum transfers (*lsm*) and value added taxes (*vat*) are the most effective financing designs, followed by household exemptions (*exe_house)*, producers' exemptions (*exe_prod*) and oil taxation *(fueltax)*. The excess burden is higher under those tax systems where the tax base is narrower and the substitution options are also lower. When *exe_prod* and *fueltax* are set, the ability of consumers to substitute other energy-goods for electricity or fuel is more limited, and thus the welfare results are worse.

Table 3: Overall economic effects per policy design.

Scenarios	***exe_prod***	***exe_house***	***lsm***	***vat***	***fueltax***
Welfare (in % compared to BaU)	-0.018	0.001	0.063	0.063	-0.025
CO_2 (in % compared to BaU)	2.23	1.02	3.09	3.15	-4.61
Subsidy on renewables (in €bn)	5.40	5.63	5.38	5.32	5.28
Share of renewables (% total electricity)	38.09	39.21	37.74	37.74	38.09
Supply of renewables	14.92	14.92	14.92	14.92	14.92

All scenarios have as a common feature the fact that they modify or eliminate the surcharge for financing the promotion of RES-E. The reduction of the electricity surcharge leads to greater electricity supplies, and thus greater CO_2 emissions. Similarly, a higher electricity demand reduces the target level of renewables achieved, even if the different scenarios achieve the same supply of renewables. Thus, to achieve the pre-scenario target for renewables — equivalent to 40 % of the total electricity supply— higher subsidies on renewables would be needed. Under *exe_house* the electricity supply is closer to *BaU* levels (see Figure 5 below), so *exe_house* is the most effective mechanism for achieving target levels of renewables without increasing CO_2 emissions.

4.3 Sectoral impacts

Figure 5 shows how alternative financing designs affect production per sector of the economy. The main argument used by producers to defend exemptions (*exe_prod*) is the avoidance of an excessive increase in energy costs that might affect their competitiveness, especially in energy-intensive sectors. However, producers' exemptions call for greater efforts from the rest of the economy, i.e. from households. The result shows that in general the output in the *exe_prod* scenario increases with respect to *BaU*, and more markedly in the energy-intensity sectors (ein), in the electricity industry, and in those sectors that are most closely related to the electricity sector. By contrast, *exe_house* requires greater financing efforts from economic sectors. Consequently, *exe_house* reduces output with respect to *BaU*, mainly in energy intensity industries (ein). Finally, in all the scenarios the production of electricity increases but the *exe_house* scenario is the one where it increases the least, because the higher demand for electricity from households is offset by lower demand from production sectors.

The alternative scenarios all promote RES-E with no surcharge on electricity prices. Therefore, as happened under *exe_prod*, the lower the cost of electricity inputs is the lower the impacts on sectoral output will be. *Lsm* and *vat* financing designs confirm the positive impacts of economic sectors when the effort to finance the promotion of RES-E is not defrayed by industries. On the other hand, *fueltax* shows that the beneficiaries of eliminating the electricity surcharge are mainly the electricity industry, those sectors related to electricity production (such

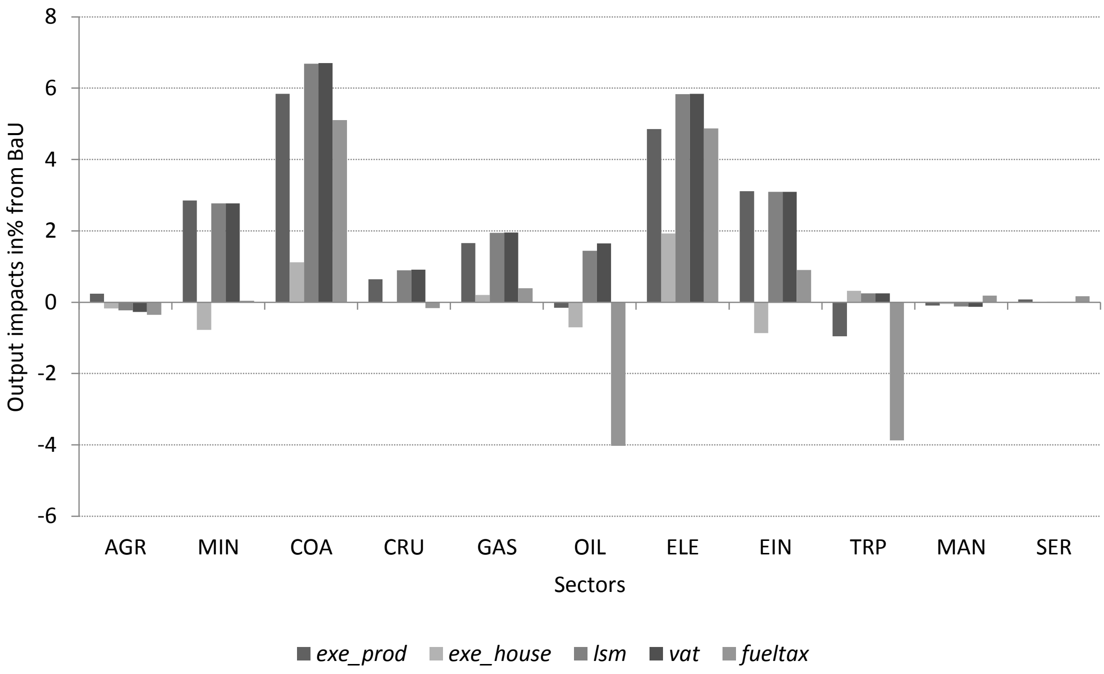

Figure 5: Impacts on output per sector and scenario (in % compared to BaU).

as coal or mining), and energy-intensive industries. However, under *fueltax* the oil sector and the sectors related to oil production and consumption, such as crude oil (cru) and transport (trp), suffer higher cost impacts. All in all, our results show general benefits when the effort to finance the promotion of RES-E is not defrayed by electricity prices.

4.4 Distributional impacts

The argument for introducing exemptions on producers (*exe_prod*) is to avoid any loss of competitiveness, but exemptions on households are aimed at avoiding excessive welfare impacts and reducing possible regressive impacts. In this vein, we present the results for the distribution impacts of the scenarios in terms of welfare (measured in terms of Hicksian equivalent variation in income[13]). Figure 6 shows welfare impacts by expenditure groups, where group 1 represents the lowest expenditure and group 20 the highest. Figure 6 clearly indicates that there are welfare gains when financing efforts are shifted from households to production sectors. This is consistent with the results obtained for the overall welfare effect (Table 3 above). Thus, exemptions on households (*exe_house)* can substantially relieve the welfare impacts and correct the undesirable regressive effects that renewable surcharge can have on the poorest households. On the other hand, exemptions on producers (*exe_prod)* comprise the most regressive of all the options. This reflects the excessive welfare impacts caused by financing the promotion of RES-E through an electricity surcharge paid by households, and also the regressive impacts of industrial exemptions. Under *exe_prod* the higher residential electricity price leads the poorest people to allocate a greater proportion of their expenditure to energy than the rich. A comparison of Figures 5 and 6 reveals an interesting trade-off between economic output and distributional impacts.

Among alternative taxes sources, *lsm* are the most effective in safeguarding against welfare losses in low-income groups, followed by *vat* and *fueltax.* Lump-sum transfers (*lsm*) and value added taxes (*vat*) confirm that there are welfare gains in most income groups from

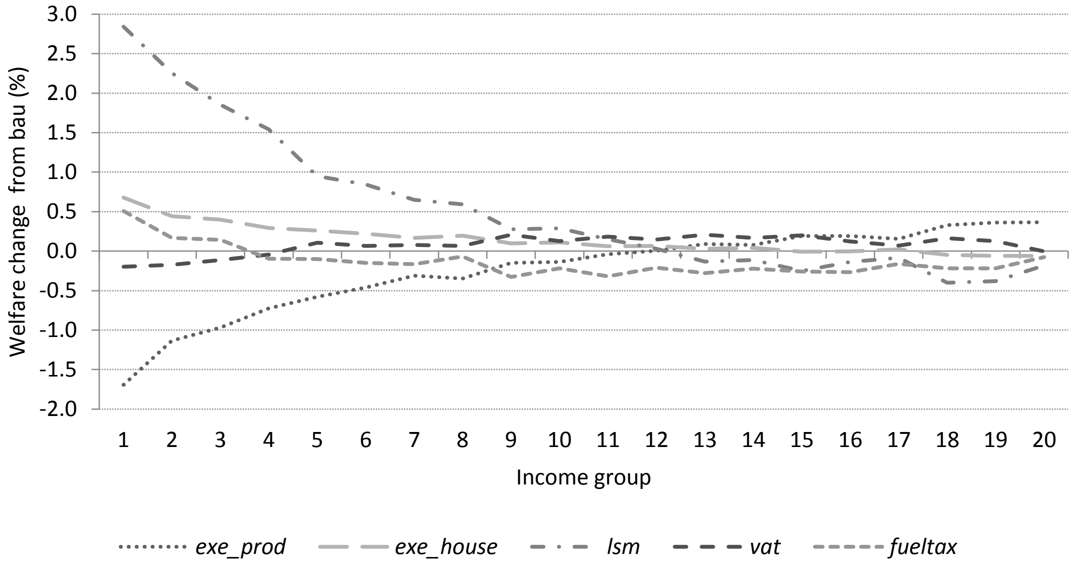

Figure 6: Welfare impacts per income group (% of Hicksian equivalent variation (HEV) in income).

13: The Hicksian equivalent variation in income denotes the amount that must be added to (or subtracted from) the BaU income of the representative consumer so that he/she enjoys a utility level equal to that in the counterfactual policy scenario on the basis of ex-ante relative prices.

eliminating the promotion of RES-E via an electricity surcharge. When the promotion of RES-E is financed through *lsm* welfare increases in the lowest income households but decreases in higher income households. On the other hand, *vat* and *fueltax* have neutral impacts from a distributional perspective. *Fueltax* results are consistent with the consumption pattern, considering that fuel consumption is similar in the different income groups. Similarly, although value added tax tends to be regressive the differentiation of tax rates for different goods in Spain offsets these regressive effects (Sanz-Sanz and Romero-Jordan, 2012). The main result that emerges from using alternative taxes sources for financing the promotion of RES-E is that the trade-off between sectoral output effects and regressiveness with the electricity surcharge can be overcome and avoided. In fact, *lsm* and *vat* show that both households and production sectors can achieve gains from the promotion of RES-E without increasing electricity bills.

Impact on consumer prices and income sources are key drivers in explaining the above-mentioned welfare and incidence effects. Greater impacts on goods or income sources more related to low income households would tend to lead to greater losses in the poorest households. Table 4 shows impacts on consumer prices and on income sources. Industrial exemptions (*exe_prod*) involve higher electricity prices for consumers and thus greater impacts on welfare (Figure 6 and Table 3). Otherwise, as expected, when *exe_house*, *lsm*, *vat* or *fueltax* are set household electricity prices fall as a consequence of the reduction in the electricity surcharge. In general, impacts on welfare and their incidence are dominated by the electricity price, because the rest of the price effects are quite modest and distributed more evenly across different goods. Only under *fueltax* does the fuel price increase notably. Secondly, the impacts on income sources are also quite modest (Table 4), with the only noteworthy case being the transfer impacts when *lsm* is set. As shown in Figure 3b, the poorest households have net benefits from transfers whereas the middle and upper classes are net transfer donors. Thus, an increase in transfers entails gains for the poorest households and welfare losses for the richest.

Table 4: Impacts on consumer prices and income sources (% compared to BaU)

Scenarios	***exe_prod***	***exe_house***	***lsm***	***vat***	***fueltax***
			Impact on consumer prices		
Food	-0.92	0.27	0.02	0.02	-0.36
Education and Leisure	-0.79	0.26	0.20	0.19	-0.12
Electricity	57.31	-19.16	-16.27	-16.25	-15.33
Fuel	-0.86	0.26	0.12	0.12	8.15
Heat	-0.89	0.34	0.08	0.09	13.02
Housing	-0.81	0.26	0.18	0.18	-0.20
Durables	-0.86	0.27	0.13	0.13	-0.21
Transport	-0.79	0.26	0.19	0.19	1.52
Other goods	-0.80	0.26	0.18	0.18	-0.20
			Impact on income sources		
Labor	-0.52	0.26	0.77	-0.32	0.44
Capital	-0.38	0.10	0.55	-0.55	-0.99
Transfer	-0.84	0.23	3.63	-1.17	-0.01

One of the main advantages of including multiple levels of households in our CGE approach is that we can then zoom in on those households that are more affected. Hence, to test for heterogeneity within income groups, Figure 7 reports the share of households where welfare loss is greater than 5 % of annual income per income group. As the households where electricity consumption accounts for the largest proportions are in the low income groups, under *exe_prod*

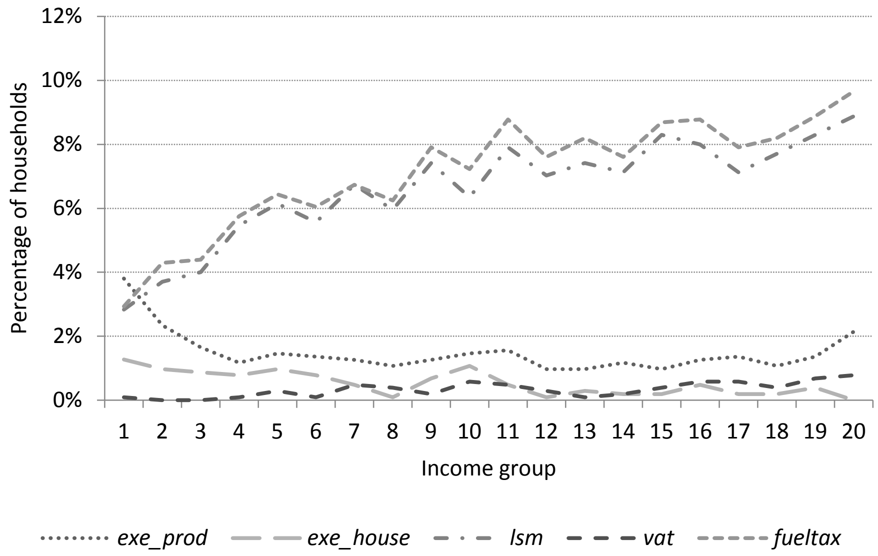

Figure 7: Percentage of households with losses greater than 5% compared to BaU per income group.

the lowest-expenditure households are found to have the greatest number of households with higher welfare losses. By contrast, few households in the highest expenditure groups have impacts greater than 5 %. On the other hand, as expected, when *lsm* is set the welfare losses increase with the income of the households. Similarly, when *fueltax* is used to finance the promotion of RES-E the highest-expenditure households are found to have the greatest number of households with higher welfare losses. Although in average terms the impact of *fueltax* is neutral (see Figure 6) when we focus on the households with the greatest welfare losses *fueltax* seems to have progressive impacts. By contrast, *exe_house* and *vat* follow a similar trend in average impacts on welfare and income groups with a large proportion of households with higher welfare losses.

Another important issue is that of the implications for energy poverty. According to some estimations in Spain, 21 % of households are at risk of energy poverty (see ACA, 2016), with the most vulnerable being those with elderly/retired people and those with children. Figure 8 reports the impacts of welfare per social group to check for possible counterproductive effects on vulnerable households. Under *exe_prod*, households of retired persons suffer the greatest welfare loss because they tend to have greater electricity expenses. This result shows that the group most vulnerable to changes in electricity prices is that of households of elderly (retired) persons. At the same time, households with elderly persons are net transfer recipients, which explains their welfare gains when *lsm* is set. Single parent households also have greater welfare losses. Such households are normally in the lower income range, for which the monetary loss represents a higher relative cost. In conclusion, measures that increase electricity prices (such as *exe_prod*) lead to greater welfare losses and regressive impacts (Figure 6), and increase welfare losses in vulnerable households at risk of energy poverty.

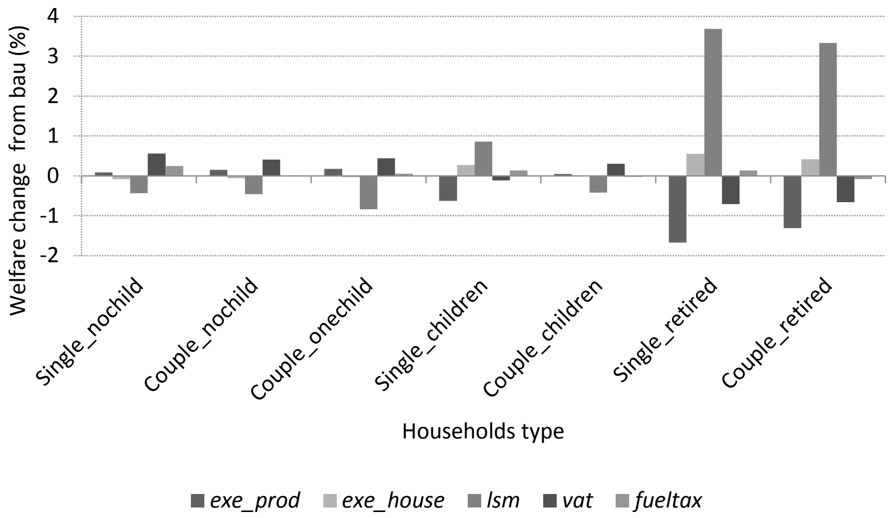

Figure 8. Welfare impacts per household type (in % of Hicksian equivalent variation (HEV) in income).

5. Conclusions

Renewable energy promotion has become a policy priority for governments around the world because of its positive environmental effects. However, there is also concern about the effect that the entry of RES-E may have on the total costs of electricity production and how this is going to affect different social groups, firms and competitiveness. In this paper we apply a computable general equilibrium (CGE) model in combination with a microsimulation (MS) model to examine the distributional implications of different schemes for financing the promotion of renewables. The schemes considered include exemptions from the RES-E surcharge on the price of electricity for producers or households, and also alternatives where the cost of renewables is not financed through the electricity bill but from other tax sources such as fuel tax, VAT or transfers.

Our results provide evidence against the use of a surcharge on electricity prices to promote renewables. We show the consequences of including exemptions from the surcharge for producers and households. Despite the obvious gains for the agent exempted, both scenarios involve greater losses for the rest of the economy. These scenarios also show a trade-off between protecting sectoral output effects and protecting low-income households. The exemptions on producers increase the negative effect on low-income households (with respect to *BaU*). This can be alleviated with exemptions for consumers, but at the expense of doing more harm to energy-intensive industries. Moreover, both scenarios show the possible regressive impacts of increasing surcharges on electricity prices. The greater the financing efforts from households are when electricity surcharges are increased (*exe_prod*), the higher the welfare and regressive impacts are. However, exemptions on households (*exe_house*) relieve welfare impacts and correct undesirable regressive effects.

The change in the electricity sector plays a decisive role in explaining performance at sectoral and household levels. Hence, under the exemption for households electricity-intensive sectors are more severely affected as they get higher electricity costs. On the other hand, under exemptions for producers, the ability of consumers to substitute other goods for electricity is lower, and thus the welfare impacts are worse. Given that low-income households devote a greater proportion of their expenditure to electricity, higher electricity prices also entail greater regressive impacts.

Finally, our simulation results show the possible benefits of alternative ways of financing the promotion of RES-E. Lump-sum transfers and value added taxes can significantly attenuate adverse effects on production sectors (especially in energy-intensive industries) and at the same time reduce the regressive effects found in the other options. As the cost of promoting RES-E is not passed on to producers, both scenarios show an increase in output. Similarly, the excess burden is lower because the tax base is larger and thus, at the same time, the substitution options are greater. However, the option of increasing the price of fuel is less clear. All in all, our results show that there are general benefits when efforts to finance the promotion of RES-E is not defrayed by the electricity supply.

References

ACA (2016). 3er Estudio Pobreza Energética en España - Nuevos Enfoques de Análisis. Asociación de Ciencias Ambientales, ACA.

Armington, P.S. (1969). A Theory of Demand for Producers Distinguished by Place of Production. IMF Staff Papers, 16 (1), 159–78.

Arto, I., Genty, A., Rueda-Cantuche, J.M, Villanueva, A., and Andreoni, V. (2012). Global resources use and pollution, volume 2/ Country Factsheets. JRC scientific and policy reports. Report EUR 25462. Joint Research Centre.

CEOE (2014). Publicaciones CEOE: Energía y competitividad : propuestas del sector empresarial. CEOE 2014.

del Río, P., and Mir-Artigues, P. (2014). Combinations of Support Instruments for Renewable Electricity in Europe: A Review. Renewable and Sustainable Energy Reviews 40 (December): 287–95. doi:10.1016/j.rser.2014.07.039.

del Rio, P., Mir-Artigues, P. and Trujillo-Baute, E. (2016). Analysing the Impact of Renewable Energy Regulation on Retail Electricity Prices. IEB Working Paper 2016/19

EC (2011). Roadmap for moving to a low-carbon economy in 2050, COM/2011/0112, European Commission, Brussels.

EC (2014). A policy framework for climate and energy in the period from 2020 up to 2030, COM/2014/15, European Commission, Brussels.

Eurostat (2016). Renewable energy statistics. 2016. http://ec.europa.eu/eurostat/statistics-explained/index.php/Renewable_energy_statistics.

Deaton, A. and Muellbauer, J. (1980). An almost Ideal Demand System. American Economic Review, 70, 312–326.

FS and UNEP (2016). Global Trends in Renewable Energy Investment 2016. Frankfurt School-UNEP Centre/BNEF, Frankfurt am Main.

Fischer, C. (2010). Renewable Portfolio Standards: When Do They Lower Energy Prices? The Energy Journal 31(1):101–19.

Fischer, C. and Preonas, L. (2010). Combining Policies for Renewable Energy: Is the Whole Less Than the Sum of Its Parts? International Review of Environmental and Resource Economics: Vol. 4: No. 1, pp 51-92. http://dx.doi.org/10.1561/101.00000030

Fullerton, D. (2008). Distributional Effects of Environmental and Energy Policy: An Introduction. Working Paper 14241. National Bureau of Economic Research. http://www.nber.org/papers/w14241.

Gelabert, L., Labandeira, X. and Linares, P. (2011). An Ex-Post Analysis of the Effect of Renewables and Cogeneration on Spanish Electricity Prices. Energy Economics, Supplemental Issue: Fourth Atlantic Workshop in Energy and Environmental Economics, 33, Supplement 1 (December): S59–65. doi:10.1016/j.eneco.2011.07.027.

Genty, A., Arto, I., and Neuwahl, F. (2012). Final database of environmental satellite accounts: technical report on their compilation. WIOD Documentation.

Graham, P., Thorpe, S., and Hogan, L. (1999). Non-competitive market behaviour in the international coking coal market. Energy Economics, 21(3):195–212.

IEA (2015). Energy Policies of IEA Countries: Spain2015 Review, OECD/IEA, International Energy Agency, Paris.

IEA (2016). Key Renewables Trends, IEA, International Energy Agency, Paris.

INE (2016a). Contabilidad Nacional de España. Base 2002. Marco input-output. Tabla Input-Output, Año 2007. Instituto Nacional de Estadística. www.ine.es.

INE (2016b). Encuesta continua de presupuestos familiares, base 1997. Instituto Nacional de Estadística. www.ine.es

IPCC (2012). Renewable Energy Sources and Climate Change Mitigation: Special Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge.

IRENA (2016). Renewable Energy Benefits: Measuring The Economics. International Renewable Energy Agency, Abu Dhabi.

Krichene, N. (2002). World crude oil and natural gas: a demand and supply model. Energy Economics, 24(6):557–576.

Koesler, S., and Schymura, M. (2015). Substitution Elasticities in a Constant Elasticity of Substitution Framework – Empirical Estimates Using Nonlinear Least Squares. Economic Systems Research 27, 101–121. doi:10.1080/09535314.2014.926266.

Mir-Artigues, P., Cerdá, E., and del Río, P. (2015). Analyzing the Impact of Cost-Containment Mechanisms on the Profitability of Solar PV Plants in Spain. Renewable and Sustainable Energy Reviews 46 (June): 166–77. doi:10.1016/j.rser.2015.02.005.

Neuhoff, K., Bach, S., Diekmann, J., Beznoska, M., and El-Laboudy. T. (2013). Distributional Effects of Energy Transition: Impacts of Renewable Electricity Support in Germany. Economics of Energy & Environmental Policy 2 (1). doi:10.5547/2160-5890.2.1.3.

Poterba, J.M. (1990). Is the Gasoline Tax Regressive? National Bureau of Economic Research.

Rausch, S. and Rutherford, T.F. (2007). Computation of Equilibria in OLG Models with Many Heterogeneous Households. Ruhr Economic Paper No. 15.

Ringlund, G.B., Rosendahl, K.E. and Skjerpen, T. (2008). Do oilrig activities react to oil price changes? An empirical investigation. Energy Economics 30: 371–396.

Rutherford, T. (2002). Lecture notes on constant elasticity functions.

Rutherford, T.F. and Tarr, D.G. (2008). Poverty effects of Russia's WTO accession: Modeling "real" households with endogenous productivity effects. Journal of International Economics, 75(1):131–150.

Sanz-Sanz, J.F. and Romero-Jordán, D. (2012). Efectos recaudatorios y distributivos en 2012 de algunas opciones de reforma del IVA. Impacto sobre el sector de los hogares. Cuadernos de Información Económica nº 228 29 de junio de 2012.

Sáenz de Miera, G., del Río González, P., and Vizcaíno, I. (2008). Analysing the Impact of Renewable Electricity Support Schemes on Power Prices: The Case of Wind Electricity in Spain. Energy Policy 36 (9): 3345–59. doi:10.1016/j.enpol.2008.04.022.

Schmalensee, R. (2012). Evaluating Policies to Increase Electricity Generation from Renewable Energy. Review of Environmental Economics and Policy 6(1):45–64. doi:10.1093/reep/rer020.

Sensfuß, F., Ragwitz, M., and Genoese, M. (2008). The Merit-Order Effect: A Detailed Analysis of the Price Effect of Renewable Electricity Generation on Spot Market Prices in Germany. Energy Policy 36 (8): 3086–94. doi:10.1016/j.enpol.2008.03.035.

Traber, T., and Kemfert, C. (2009). Impacts of the German Support for Renewable Energy on Electricity Prices, Emissions, and Firms. The Energy Journal 30(3):155–78.

Wadud, Z., Graham, D. J., and Noland, R. B. (2009). Modelling fuel demand for different socio-economic groups. Applied Energy, 86, 2740–9.

Annex A: Almost Ideal Demand System, estimated as a seemingly unrelated regression

	food	Housing	Fuel	Electricity	Heat	Transport	Education and Leisure	Durables
ln (p_food)	0.030**	-0.007	-0.018*	-0.001	0.001*	0.014	-0.057*	-0.011
ln(p_housing)	-0.007	0.176*	-0.012*	0.011*	0.001	-0.003	-0.052*	-0.110*
ln(p_fuel)	-0.018*	-0.012*	0.029*	-0.001*	-0.001*	-0.014*	-0.017*	0.037*
ln(p_electricity)	-0.001	0.011*	-0.001*	0.015*	-0.001*	-0.004*	-0.008*	-0.007*
ln(p_heat)	0.001*	0.001	-0.001*	-0.001*	0.006*	-0.001*	-0.003*	-0.002*
ln(p_transport)	0.014	-0.004	-0.014*	-0.003*	-0.001*	0.042*	0.013	-0.017
ln(p_leisure & education)	-0.057*	-0.052*	-0.017*	-0.008*	-0.002*	0.013	0.131*	-0.014
ln(p_durables)	-0.011	-0.110*	0.037*	-0.007*	-0.002*	-0.017	-0.015	0.097*
ln(p_other goods)	0.048*	-0.001	-0.003	-0.006*	-0.001*	-0.029*	0.008	0.028**

Table A1: Almost Ideal Demand System, estimated as a seemingly unrelated regression, estimates rounded to 3 digits.

* Statistically significant at the 5 % level.

** Statistically significant at the 10 % level

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