Could a crowd of small actions represent a significant change to reduce emissions? A CGE analysis for Spain

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Resumen: Over the last years, reducing emissions is one of the main objectives of European Community Environmental Policy, which sets emission ceilings for each member state (Directive 2001/81/EC). As a consequence, countries organize their contribution to environmental improvement through national strategies to reach the European Union mandates. This drives to design strategies that involve the population as a whole. In Spain, the Energy Saving and Efficiency Plan (2011-2020) aims to reduce the energy consumption by 20% in 2020 pursuant to the methodological recommendations on saving measurement and verification by the European Commission.

In this context, we assess the environmental impact of some measures aimed to the consumers through the Spanish strategy using a dynamic Computable General Equilibrium (CGE) model calibrated on 2009 Spanish data. Our analysis focuses on the impact on greenhouse gases (GHG) and sulphur oxide (SO_x). Specifically, we generate representative scenarios for certain changes that are designed to involve each consumer consistent with the measures proposed in the Spanish strategies, analyzing the impact of improvements in the electricity savings (for lighting per dwelling and electrical appliances) and the promotion of sustainable means of transport through the transfer of passenger vehicle traffic to collective modes.

With these scenario analyses, we are interested in answering the following question with regard to policy options: What extent could a crowd of small actions mean a significant change to reduce emissions in the society as a whole and contribute to environmental mandates?

Results aims to provide guidelines for public deciders to consider the profitability of the alternative strategies and shed light on the influence of household consumption patterns and their sensitivity to environmental initiatives.

Palabras Clave: Consumers, Emissions abatement, CGE model, Rebound effect
Clasificación JEL: Q4, Q51, Q56, Q57, C67, C68

1. Introduction

Each individual plays a role in economic systems through both production and demand side, which has thus significant influence on the environment. This drives to design strategies that involve the population as a whole. Over the last years, there has boosted investments in technological improvements focusing on increased efficiency. For instance, most of electric appliances that are sold nowadays consider any type of environmental improvement. Furthermore, the promotion of public transport over private transport as well as citizen awareness of the relevance of the environment takes part in all the campaigns of any government. The main aim of these improvements is to reduce emissions released into the environment. In this context, European Community Environmental sets emission ceilings for each member state (Directive 2001/81/EC). Spain, the Energy Saving and Efficiency Plan (2011-2020) aims to reduce the energy consumption by 20% in 2020 pursuant to the methodological recommendations on saving measurement and verification by the European Commission. The Spanish energy planning makes up a coherent whole leading to the objective to improve the final energy intensity by 2% year-on-year for period 2010-2020. It focuses its efforts on 6 sectors (Industry, Transport; Building (residential and service); Equipment (residential and service); Public Services; and Agriculture and fisheries) and specifies particular measures for each of them to involve direct, indirect and end-users.

Indeed, there is a growing recognition that the responsibility for atmospheric emissions lies not only with the producer but also with the end users of goods (Lenzen et al., 2007). However, the bulk of the discussion in the literature is based on analyzing the effects from changes in the production side, rather than consumer side.

In order to fill this gap, we assess the environmental impact of some measures aimed to the consumers through the Spanish strategy using a dynamic Computable General Equilibrium (CGE) model calibrated on 2009 Spanish data. Our analysis focuses on the impact on greenhouse gases (GHG) and sulphur oxide (SO_x). Specifically, we generate representative scenarios for certain changes that are designed to involve each consumer consistent with the measures proposed in the Spanish strategies, analyzing the impact of improvements in the electricity savings (for lighting per dwelling and electrical appliances) and the promotion of sustainable means of transport through the transfer of passenger vehicle traffic to collective modes (bus, train and underground).

With these scenario analyses, we are interested in answering the following question with regard to policy options: What extent can a crowd of small actions mean a big change to reduce emissions in the society as a whole and contribute to environmental mandates?

As emissions, we treat emissions generated in the production processes required to meet private demand as indirect household emissions. Under this finalist assumption, we can also link the emissions of economic activities to different components of final demand (i.e. exports, public expenditure and investment). Moreover, emissions generated from heating, cooking, car use and so on are treated as direct household emissions depending on the amount and kind of energy used (fuel, gas, coal, etc.). This approach has been applied in a number of studies to calculate environmental impacts using the input-output model, including Ferng (2002), Resosudarmo (2003), and McDonald and Patterson (2004).

On the other hand, we take into account the “rebound” effects (Jevons, 1985). The rebound effect is usually discussed in connection with energy saving and energy efficiency improvement, which essentially implies a lower energy bill. Given that improvements in energy efficiency alter the mix of both final and input demands, increase consumers’ real income, and expand firms production and export possibilities, the prices will undergo numerous, and complex adjustments through the whole economy. In this context, general equilibrium analysis seems suitable to predict the ultimate result of these changes due to the fact that these models allow us to capture changes in prices, consumption, production, and technology. While partial equilibrium analysis focuses on the sector affected by a policy assuming the rest of the economy is not affected, CGE models consider other sectors and regions and incorporate constraints and feedbacks between different economic sectors that allows for a more complete assessment. Therefore, CGE models have increasingly been used in empirical analyses of changes in energy efficiency improvements and their rebound effects (e.g. Semboja (1994) in Kenyan economy; Hanley et al. (2006) in Scotland; Anson and Turner (2009) also in Scotland, using a dynamic CGE model; Barker et al. (2007) for the UK economy; Barker et al. (2009) for the world economy; Turner and Hanley (2011) for the Scottish economy, and Duarte et al. (2014) for a regional economy in Spain).

Thus, advancing in the Spanish context with a methodological improvement using a dynamic model, our work aims at evaluating some sustainable changes proposed in the national strategies against climate change through efficiency improvements in household energy and transport use that involves technical change. Our results aims to provide guidelines for public deciders to consider the profitability of the alternative strategies and shed light on the influence of household consumption patterns and their sensitivity to environmental initiatives.

The rest of the paper is organized as follows. Section 2 presents the methods and data we work. Section 3 describes the baseline scenario with the pollution structure of the Spanish economy, the scenarios simulated and the results obtained. Section 4 presents the main concluding remarks.

2. Material and methods

A dynamic CGE model is built and designed to the Spanish economy in 2005. This CGE model is calibrated using the Spanish Input-Output Framework (IOFA-05) available in INE (2005a). The input-output table has 34 economic activities, two factors of production (labour and capital), and other accounts as Households, Companies, Saving/Investment, Government, and a Foreign Sector. The Foreign sector consists of two other accounts: transactions carried out with the rest of the European Union (EU), and with the Rest of the World (ROW). In line with the objective of this study, we take a special interest in energy sectors, which are disaggregated into for sectors: coal, refined petroleum products, electricity and gas. Additionally, the agribusiness industry is also broken down into five sectors: meat industry, dairy, other food industries, beverages and tobacco. This high level of disaggregation focusing on sectors linked to energy allows us to consider specific production structures according to some substitution assumptions.

2.1. Emissions account

The emissions analysed in this paper comprise greenhouse gases (GHG) and sulphur oxide (SO_x). According to the guidelines of the Kyoto Protocol, greenhouse gases comprise carbon dioxide (CO_2), methane (CH_4), and sulphur hexafluoride (SF_6). As the greenhouse gases have differing Global Warming Potential (GWP), we consider total GHG emissions in kilotons of equivalent carbon dioxide (Kt of CO_{2eq}), calculated on the basis of the factors published in IPCC (2007).

The emissions information has been developed using Emissions satellite accounts provided by the Spanish National Statistics Institute (INE, 2005b).

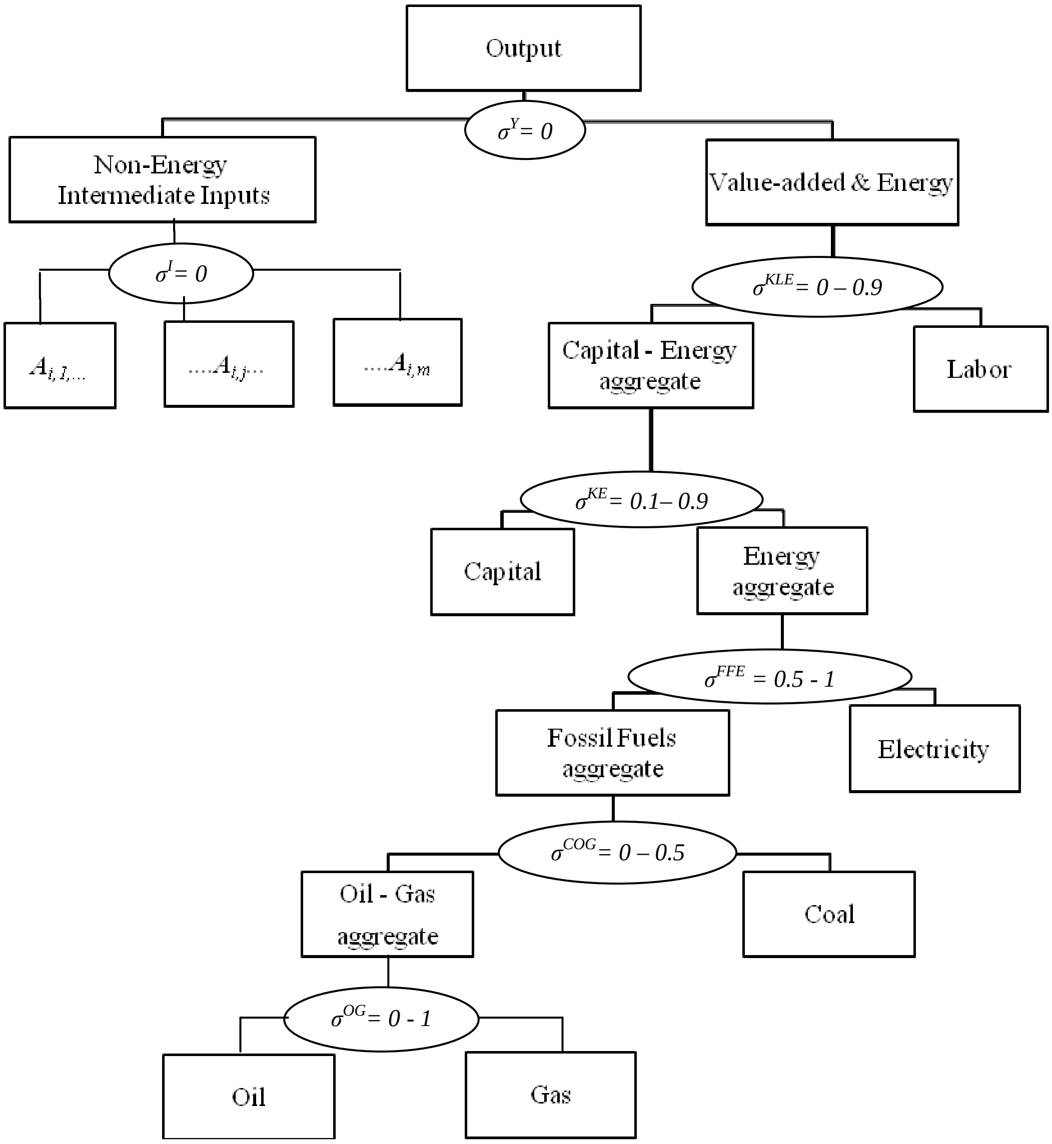
2.2. The Computable General Equilibrium model

In our analysis, we develop a multi-sector, dynamic CGE model for the Spanish economy. This section outlines the model applied. The elasticity parameters were selected on the basis of a review of the literature and studies in this area (De Schoutheete, 2012; Burniaux and Truong, 2002; Rutherford and Paltsev, 2000; Paltsev et al., 2004; De Melo and Tarr, 1992, for the CET function; Hertel, 1997, for the Armington approach).

Figure 1 provides an overview of the production technology. Producer behavior is specified through a six-stage nested CES production function and through a zero-profit condition, following a production structure similar to the GTAP-E model (Burniaux and Truong, 2002). On the top level of the production structure, firms minimize their costs by choosing an optimal combination of the non-energy intermediate inputs and the composite of value-added and energy input (VAE). The VAE contains labour and the aggregate of capital and energy. On the third level the aggregate of capital and energy is obtained through a CES combination of the capital factor and the energy composite. Since this study focuses on assessing energy issues, it pays special attention to the energy sector modeling. The total demand for energy is a CES composite of electricity and a fossil fuels aggregate, which is a CES composite of coal and oil-gas composite.

On the other hand, output in each sector can be earmarked to domestic or foreign demand through a CET function. We also adopt an Armington approach, in which domestic and imported goods are imperfect substitutes with different elasticities.

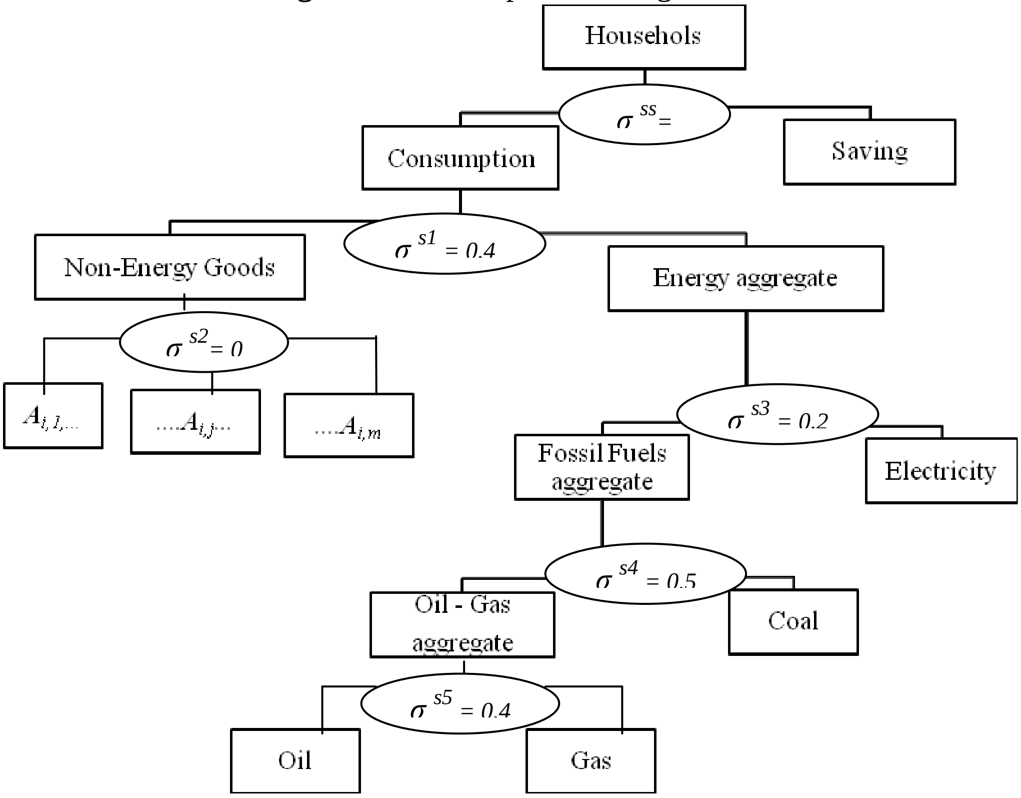
Figure 1. Structure of the model



Source: Own elaboration.

Consumer preferences are defined by a four-stage nested CES utility function. See in Figure 2 the nested structure for the different goods: energy goods (Oil, Gas, Coal and Electricity) and rest of goods.

Figure 2. Consumption nesting structure



Source: Own elaboration.

The consumer maximizes the total utility subject to the budget constraint. Income comes from the sale of factor endowments and direct transfers from the Government and other institutions, and disposable income is spent on consumption, tax payments, and transfers to other institutions, while the residual is saved. The Government receives taxes from the representative agent and transfers from other institutions. It spends them on consumption, savings and transfers to other agents. Total public expenditure is modeled through a fixed coefficients structure. The lump-sum transfers between the Government and the consumer are endogenously adjusted to ensure the same budget balance for the Government as in the baseline. The NPISH receives income from the sale of factor endowments and direct transfers from other institutions, which are spent on consumption, savings and transfers to other agents.

Our model also includes a wage curve specification as an organizing framework, following Blanchflower and Oswald (1990), that allows us to consider imperfect competition mechanisms within the labour market when analyzing unemployment. The value of the elasticity of real wages with respect to unemployment is -0.07, in line with other recent Spanish results (García-Mainar and Montuenga-Gómez, 2012) and the evidence on the existence of a wage curve in Spain (see in detail De Shoutheete, 2012; Sanromá and Ramos, 1999; Villaverde, 1999). This wage curve corresponds to the empirical evidence for Spain on the inverse relationship between the level of real wages and the unemployment rate. For this purpose, we introduce the wage curve in the model, following Küster et al. (2007), that requires including an additional equation in the model to substitute flexible wages by a wage equation, in which the wage rate is linked to the level of unemployment.

In the model, we consider two external regions: the rest of the European Union, and the rest of the world (ROW). The exchange rate between Spain and the European Union is fixed and is used as the numeraire, while trade balance adjusts, as Spain trades in euros. The exchange rate with ROW is also kept constant.

Total investment equals total saving, where savings are composed of savings from all institutions. The market balance conditions are satisfied by adjusting relative prices. Zero degree price homogeneity is assumed for all supply and demand functions in the model. In line with the general equilibrium framework, only relative prices are relevant for the specification of supply and demand for goods in quantitative terms. The values of the main dynamic model parameters were obtained from actual average data for the region in the period 2005-2013 (INE, 2005-2013). Specifically, the annual interest rate is 4.28% and the growth rate is 0.2%. The relationship between capital and investment in the steady-state is obtained from the calibration of the model using SAM data. The model is programmed as a mixed complementarity problem (MCP) using GAMS/MPSGE (Rutherford, 1999), and is solved with the PATH algorithm.

2.3. Attribution of emissions to final demand

The emissions estimated in the CGE model take into account both households' direct emissions and direct and indirect emissions from production activities.

$$E^{TOT} = E^{DH} + E^{DIA}$$

Where E^{TOT} are total emissions, E^{DH} are households' direct emissions and E^{DIA} are direct and indirect emissions from all economic activities.

E^{DH} emissions result from household energy consumption. These emissions are obtained as the product of the vector $\mathbf{i} = (i_e)$ of emissions per unit of each type of energy by household energy consumption vector $\mathbf{c} = (c_e)$. The index e refers to the type of energy product ("Coal", "Refined oil" and "Gas"). Note that electricity consumption is not included, because statistically its emissions are attributed to the electricity sector in their entirety.

E^{DIA} emissions are those that occur during the production process, including emissions relating to electricity consumption. Using the input-output model, we can relate emissions from production activities with the monetary flows applying the following expression (see Sanchez-Chóliz et al. (2007)).

$$E^{A} = \mathbf{d}\,(\mathbf{I}\text{-}\mathbf{A})^{-1}\mathbf{s}$$

Where **d** is a unit vector of emissions (Kt of CO_{2eq} per monetary unit of output); $(\mathbf{I}\text{-}\mathbf{A})^{-1}$ is the Leontief inverse matrix; **s** is the vector of final demand or a component of final demand; and then E^{A} will be the emissions from productive activities necessary to meet demand **s**.

Therefore, we use this input-output model to attribute emissions to the components of final demand once emissions generation is modelled in the CGE model (see also Turner et al., 2012).

3. Results

After specifying the CGE model and calibrating it to SAMA-05, we proceed to make changes in the structure of private consumption. In the CGE model, these changes affect the actual prices of goods and services and determine the behaviour of economic agents, defining a new equilibrium. We can quantify the impact of the changes made by comparing the magnitudes of the new equilibrium with the baseline scenario.

3.1. Description of the baseline scenario

The emissions from economic activities were distributed between the components of final demand using the input-output model. As shown in Table 1, economic activities account for more than 80% of GHG and SOx emissions. Emissions associated with households and exports (embodied emissions) are the most significant According to this structure, households' indirect emissions far outweigh their direct emissions.

Table 1. GHG and SOx emissions of associated with final demand

	GHG (Kt)	%	SO_2(Tn)	%
Households' direct emissions (1)	77,084	*16.64*	19	*1.42*
Emissions of production activities (2)	386,260	*83.36*	1300	*98.58*
Households	171,449	*37.00*	666	*50.51*
Export	76,062	*16.42*	256	*19.45*
Government	54,500	*11.76*	129	*9.76*
NPISH	3,035	*0.65*	6	*0.49*
Investment	81,214	*17.53*	242	*18.38*
Total emissions (1+2)	**463,344**	***100.00***	**1319**	***100.00***

Source: Own elaboration.

3.2. Description of scenarios

In line with the objectives stated above, we simulate the following two scenarios:

Scenario 1: Electricity saving in the domestic sector

Electricity saving in the domestic sector: Saving is achieved through an efficient improvement in household energy use. We achieve this goal through replacement of obsolete or low-efficiency domestic devices with appliances labeled Class A or higher.

Scenario 2: Transport substitution

In the second scenario, we simulate a change in the means of transport. This scenario models again an improvement in efficiency. The ultimate objective of this measure is to improve urban mobility by fostering more efficient modes of transport (especially public transport) and reducing low-occupancy use of private cars.

In both scenarios, we consider a logistic evolution following a Gompertz function. This assumption allows us to evaluate the rebound effects triggered by technical change, in line with the rebound literature in CGE models. The efficiency parameter is included in the consumption function.

3.3. Results

Table 2 shows that an improvement in efficiency in electricity provokes an increase in demand for non-electricity goods. It encourages total consumption and the consumption of electricity sector at the same time. We also can observe a fall in electricity generation and a small increase in the price of power, as well as falls in total output and total exports. Unemployment rate rises while real wage decreases. But, the welfare level of the economy is enhanced.

Table 2. General effects of electricity improvement (% change with respect to the baseline scenario)

Macroeconomic results	**2020**	**Sectoral & emissions results**	**2020**
Total production	-0.064	Electricity production	-4.301
Total imports	0.231	Electricity consumption	-17.974
Total exports	-0.008	Electricity price	0.191
Total private consumption	1.244	Electricity imports	-3.772
Capital investment	0.000	Electricity exports	-4.832
Government	0.000	Households direct emission (GHG)	3.32
Unemployment	3.284	Households direct emission (SO)	3.32
Wages	-0.461	Emissions of production activities (GHG)	-1.35
Exchange rate	0.000	Emissions of production activities (SO_X)	-2.87
Welfare level	0.622	**Total emissions (GHG)**	**-0.57**
CPI	-0.235	**Total emissions (SO_X)**	**-2.78**

Source: Own elaboration.

As in the case of electivity improvement, an improvement in efficiency in transport sector provokes an increase in demand for non- transport goods that encourages total consumption, as we can see in Table 3. We can observe a fall in transport production, but we can observe improvements in the economy in 2020 with increases in total output and decreases in unemployment.

Table 3. General effects of transport improvement (% change with respect to the baseline scenario)

Macroeconomic results	**2020**	**Sectoral & emissions results**	**2020**
Total production	0.117	Transport production	-6.865
Total imports	1.184	Transport consumption	-22.596
Total exports	0.738	Transport price	0.187
Total private consumption	3.241	Transport imports	-6.485
Capital investment	0.000	Transport exports	-6.980
Government	0.000	Households direct emission (GHG)	2.59
Unemployment	-0.442	Households direct emission (SO)	2.59
Wages	-1.312	Emissions of production activities (GHG)	-1.51
Exchange rate	0.000	Emissions of production activities (SO_X)	-0.54
Welfare level	1.620	**Total emissions (GHG)**	**-0.83**
CPI	-1.342	**Total emissions (SO_X)**	**-0.49**

Source: Own elaboration.

Table 4 shows that electricity savings lead to reductions in total emissions (GHG and SOx). They are due to reductions in emissions of production activities. But we can note increases in households direct emissions due to increased consumption of coal, gas and refined petroleum products provoked by the rebound effect. Again, transport improvements lead to reductions in total emissions (GHG and SOx). They are due to reductions in emissions of production activities. But we can note increases in

households direct emissions due to increased consumption of coal, gas and refined petroleum products.

Table 4. Effects on atmospheric emissions

	GHG (Kt)		SOx (Kt)	
	Sce1	Sce2	Sce1	Sce2
Households' direct emissions (1)	2641	2055	0.644	0.501
Coal	10	8	0.002	0.002
Refined petroleum products	2261	1768	0.551	0.431
Gas	370	279	0.090	0.068
Emissions of production activities (2)	-5382	-6018	-38.481	-7.184
Households	-3011	-1511	-32.801	2.559
Electricity	-4756	445	*-38.555*	*5.027*
Transport	158	-3353	*0.466*	*-10.579*
Other products and services	1587	1398	*5.288*	*8.111*
Export	-3	-1186	-0.329	-1.909
Government	-33	-85	-0.258	-0.680
NPISH	-2313	-3127	-4.902	-6.622
Investment	-21	-110	-0.191	-0.531
Total emissions (1+2)	-2741	-3964	-37.837	-6.683

Source: Own elaboration.

4. Concluding remarks

This paper has examined the impact of possible changes in consumer behaviour on atmospheric emissions in the Spanish economy. These changes are in line with the current strategies for reducing emissions. To achieve this objective, a dynamic CGE model was calibrated to the economic data for Spain. This model allows us to evaluate effects of changes in consumption patterns by 2020 in line with the Energy Saving and Efficiency Plan (2011-2020).

The results from the baseline scenario suggest that both SO_x and GHG emissions are concentrated in a few economic activities, in particular agriculture and the energy sectors. Economic activities account for more than 80% of GHG and SOx emissions. Indeed, emissions associated with households and exports (embodied emissions) are the most significant.

As scenario analysis, we have also simulated two measures established in the Energy Saving and Efficiency Plan in Spain, which are directly related with changes in household consumption, i.e., the electricity saving in households (Scenario 1) and the substitution of the private car by train or bus travel (Scenario 2). The main insights of this paper are wide-ranging. First, an improvement in efficiency in electricity or transport sectors provoke an increase in demand for non-electricity or non-transport goods, respectively, that encourages total consumption and both electricity or transport sector. In the case of electricity improvement, total production falls and unemployment rate rises. But, the welfare level of the economy is enhanced. In the case of transport improvement, we observe increases in total output, exports and imports in 2020, and unemployment declines. Both improvements lead to reductions in total emissions (GHG and SOx). They are due to reductions in emissions of production activities.

Second, these policies of savings in electricity/transport in households are very efficient from an environmental point of view. Nevertheless, it should be noted that it provokes increases in GHG and SOx emissions in household direct emissions, due to increased consumption of coal, gas and refined petroleum products (rebound effect).

Third, renewable resources should be promoted to avoid these increases in emissions.

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