Consumption patterns, technological changes and emissions in a regional economy

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Abstract

The aim of this paper is to analyze the impact of changes in consumption and production technology on GHG emissions in Aragon. We use an Applied General Equilibrium Model calibrated from the SAM of Aragon in 2005, built for this purpose, in which private consumption is disaggregated into eight classes of households based on income. Through some simulations introduced in the AGEM, we examine three issues: homogenization of consumption patterns, impacts of improvements in technological efficiency and the introduction of a green tax. Results show, in relation to consumption patterns, that the inverse relationship between household income and the emission intensity contrasted in the baseline scenario does not hold when total emissions of the economy are considered. Moreover, technological improvements in the major polluting industries do not correspond to "greening technology", and demand effect is the major force that contributes to increases in emissions. Finally, the introduction of tax on emissions has reduced emissions level mainly by limiting the effect demand.

Keywords: Atmospheric emissions, Aragones Economy, Applied General Equilibrium Model, Social Accounting Matrix.

Topic: 4, 5 o 9.

1. Introduction

Nowadays, it is widely recognized that unsustainable production and consumption have a real social and environmental impact around the world. There is an international consensus that climate change is real and it has an anthropogenic origin.

Chapter 4 of Agenda 21 underlines the need to change consumption and production patterns, by stating that ‘the major cause of the continued degradation of the global environment is the unsustainable pattern of consumption and production, particularly in industrialised countries. [...] Changing consumption patterns will require a multi pronged strategy focusing on demand, meeting the basic needs for the poor, and reducing wastage and the use of finite resources in the production process.’ UN, (1993).

There is a consensus that the responsibility of GHG emissions is not associated only with who produces it, but to the final user of goods and services even if these are imported from other economies. Munksgaard *et al*., (2001).The use of consumption perception in the analysis of GHG emissions allows understanding the consumption-environment connection and provides new information for identifying those areas of consumption in which private households can make significant contributions to environmental sustainability. This approach was used in numerous studies with the objective to link the household consumption patterns to the level of greenhouse gas emissions. A review of studies on household energy use (and CO_2 emissions) can be found in Hertwich (2005).

In this context, our paper focuses on the influence of changes in consumption and production on emissions of greenhouse gases[1] (GHG) in a regional economy, Aragon, situated in the Northeast of Spain. These impacts are estimated using an Applied General Equilibrium Model (AGEM). As is known, these models are used to simulate and determine the structural adjustments as a result of shocks, technological or preferences change and economic policy. Unlike input-output models, in AGEM, the simulated shocks cause changes in relative prices and lead to a new equilibrium, where demand will be equal to supply in each market. In the first part of this work, we propose an analysis of the impact of changes in consumption patterns on GHG emissions. To do this, we modify the structure of household consumption according to different income levels. Several studies have confirmed an inverse relationship[2] between household income and the emission intensity, so the analysis proposed here is a contribution to the study of this question.

In the other side, technological change is another pivotal approach in the analysis of GHG emissions. It is expected that technological efficiency improvements reduce production costs and cause declines in the price of output which improve the

[1] According to the Kyoto Protocol, GHG are: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs).

[2] This relation was analysed firstly in Herendeen (1978), and later in Peet *et al*. (1985) for New Zealand, Biesiot and Noorman (1999) for Netherland, Lenzen *et al*. (2004) for Australia, Cohen *et al*. (2005) for Brazil, Roca and Serrano (2007) and Mainar (2010) for Spain. According to Lenzen (1998), Wier *et al*. (2001) and Weber and Mathew (2008), the energetic relation can be extended to the case of GHG emissions. Kerkhof *et al*. (2009).

competitiveness of the economy (see Okushima and Tamura, 2010). Otherwise, those technological changes can create an opportunity to reduce GHG emissions through "greening process" or increase the energy intensity when some inputs are substituted by others more intensive in energy and emissions.

Generally, we can not expect that economic activities adopt voluntarily new technologies of production in order to limit their environmental impact. In this context, ecological taxes include the environmental cost in the price of goods and reduce pollution by shifting behaviour away from polluting activities, but they also encourage the development of new technologies that make pollution control less costly. Moreover, revenue resulting from this tax may generate a second dividend and government can use it for environmental improvements programs, lower other tax rates to correct income distribution or improve the social welfare.

It can be seen in an analysis of empirical studies about environmental tax effects, Bosquet (2000), that the introduction of the ecological tax would cause reduction in emissions in 84% of simulations (first dividend), and helps to create jobs in 73% (second dividend) when this tax is accompanied by a reduction in labour taxes. In Spain, under the assumption of neutrality of fiscal revenues, the double dividend hypothesis of a tax on CO2 emissions has been contrasted at the national level in Gomez (2002), Rodriguez (2003), Manresa and Sancho (2005) of Schoutheete (2006)), and at the regional one in André *et al*. (2005), when the ecological tax is accompanied by a reduction of payroll tax of the employers to Social Security.

In this context, the second part of this study considers two strategies related with technological changes. First, we analyze the effects of improvements of the technological efficiency and, secondly, we consider the effect of a tax on emission in the economy. With both simulations, the objective underlined here is to analyze the capacity of economic activities in Aragon to adopt sustainable technology and how the tax could induce industries to adopt green technologies and reduce GHG emissions. Results obtained will be the starting point for a deeper study of the possible technological changes that help reduce emissions as well as the design of ecological taxes associated emissions.

The paper is organized as follows. In the first part we describe the methodology used to get the database, the model used and the simulation scenarios. The second part presents the baseline scenario of GHG emissions in Aragon. Results obtained for each simulation are analyzed in sections 4-5. Finally, we appreciate the role of strategies considered in a sustainable development of Aragon.

2. Data and methodology

The Applied General Equilibrium Model (AGEM), used in this work is based on the standard model developed by "International Food Policy Research Institute" (IFPRI). The construction of the Aragonese model involves the calibration of the AGEM to a database which describes the Aragonese economy. In this work, a new Social Accounting Matrix for Aragon was developed for the year 2005 (SAMA-05). This year was chosen as the reference year since this is the most recent year for which input-output table is available, Perez and Parra (2009).

2.1. Social Accounting Matrix for Aragon (SAMA-05)

The format adapted to construct SAMA-05 is the one proposed by the Statistical Office of the United Nations. To do this, we construct a square matrix that covers 26 economic activities, two factors of production (labour and capital) and five final demand components: “Households” (later desegregated into eight accounts), “Nonprofits Institutions”(NPI), “Societies”, “Government”, “Foreign Sector” and “Saving-Investment”. Tax account is divided into the value added tax (VAT) and taxes net of subsidies.

Basically, the SAMA-05 is an extension of input-output table of Aragon (TIOA-05) to incorporate monetary flows occurred between institutions. This sub matrix is the main contribution of SAMA-05; its elements include the distribution of the following items: “Property income” (D4), “Current taxes on income” (D5), “Other current transfers” (D7), “Social contributions” (D61) and “Social benefits other than social transfers” (D62). The distribution of these items among institutions can be seen in Mainar (2010).

As the data published in the Regional Accounting do not detail resources and uses of NPI, societies, government and foreign sector by region, we have start the estimation of the sub matrix for Aragon using data of National Accounts of Spain, INE (2005a). This source of information allows us to distribute directly D5, D61 and D62 among institutions. However, to complete the matrix flows, we have desegregated items D4 and D7, and distributed it according to the following assumptions.

Firstly, for the distribution of the item (D41: Interest), we have used as support the distribution of total assets (cash and deposits, loans and shares) published in the Financial Accounts of the Spanish Economy of 2005, facilitated by the Bank of Spain. For the rest of components of D4, the only institutions that realize payments are societies and foreign sector while resources are concentrated in a single account.

Secondly, we have used the Public Administrations Accounts of 2005, to distribute D75 (Divers current transfers) among institutions. However, in the distribution of D71 (Net premiums non-life insurance), D72 (Compensation of non-life insurance), D73 (Transfers between public administrations) and D74 (Current international cooperation), the only institution with resources from the same are societies in D71, and government in other cases.

To estimate the institutional flow sub matrix for Aragon, we proceeded to construct total vectors of resources and uses. It is assumed that resources and uses of NPI, societies, government, and foreign sector in Aragon represent the same proportion than resources / uses of Aragones households with respect to the national households. In the second step, we used the average between the sum of total uses (row vector) and sum of total resources (column vector) to distribute it among the four institutions according to the national coefficients. Once total vectors are estimated, RAS algorithm is applied to obtain the institutional flow sub matrix of Aragon which is incorporated into the SAMA-05.

As income is used in some expenditure or to increase savings, in the SAM it is necessary that the sum of each row is equal to the sum of its column. The adjustment[3] of the SAMA-05 is done by matching resources and institutions uses from the savings-investment account. The account Financing capacity/requirement of the economy has also been deduced from the difference between total savings and the total investment.

In order to analyze how income and households consumption patterns influence GHG emissions, the account of household in the SAMA-05 has been desegregated into eight groups, according to the monthly regular income intervals employed in the Continuous Household Budget Survey, INE (2005b). An aggregated version of the SAMA-05 can be seen in the Appendix (A).

2.2. Account of GHG emissions

The methodology followed to obtaining the account of GHG emissions is based on the National Accounts and Environmental Accounting Matrix (NAMEA). This model allows integrating correctly environmental information in the economic system so that concepts, definitions and accounting rules are compatible with the presentation of economic activities in national accounts.

Emissions data by type of greenhouse gas was extracted from CORINAIR inventory for Aragon DGA, (2005). Although the methodology followed in this inventory is different than the NAMEA one, this basic source collects air emissions of economic activities and households and allows estimating the account of emissions after some adjustments established in Vetrella and Tudini (2004). Therefore, emissions data obtained are expressed in tons of CO_2 equivalents. IPCC (2007).

In order to disaggregate emissions of households, we proceeded firstly to determine the physical amount of natural gas, liquefied gas, liquid fuels and fuels for car use consumed by each class from the division of household's expenditures in energetic products INE (2005b) by their corresponding prices MICT (2005).Then conversion factors are applied. Mainar (2010).

2.3. The Applied General Equilibrium Model (AGEM)

The model developed herein is based on the International Food Policy Research Institute's (IFPRI) Standard AGE model (Lofgren *et al*., 2002). Calibration procedure consists in obtaining values of the model parameters in order to replicate exactly the economic structure compiled in the SAMA-05. However, in addition to the database (SAMA-05), the calibration procedure requires certain elasticity witch must be specified exogenously. Although thoroughly documented in Lofgren *et al*. (2002), the basic model structure is presented here and Appendix (B) contains the simplified equation system used in the model.

[3] Saving propensity of institutions is situated between 2.1 and 2.5% of the national savings; this coincides with the percentage that represents the Aragones economy with respect to the national one. Similarly, the Financing capacity/requirement of the Aragonese economy is equal to 11.6% of Aragon's GDP, which close to 12% estimated in Pons (2005).

Economic activities maximize profits by minimizing costs subject to a given level of production. For the most polluting sectors (agriculture, energy and non-metallic products), constant elasticity of substitution (CES) production function is assumed at the top of technology nest. The elasticity of substitution between inputs and factor markets is ($\rho a = 0.6$) and the elasticity of substitution between labour and capital is e ($\rho v = 0.8$). In other activities, the production technology is Leontief.

Import demand is modelled using the Armington assumption which posits that demand for is differentiated by region of origin. Demand of aggregate level of consumption (Armington aggregate) is decomposed into demand for a domestic component and import component. The flexibility of substitution between domestic and import sources is presented by the Armington elasticity, which is took equal to (σ q = 0.8). At the next stage, aggregate domestic output is allocated between exports and domestic sales on the assumption that suppliers maximize sales revenue for any aggregate output level subject to imperfect transformability between exports and domestic sales, expressed by a constant elasticity of transformation (CET) function, which is equal to (σ t = 1.6).

Households receive income from production factors and transfers from government and institutions. Consumption expenditure of households is determinate as the remaining income after taxes payment, savings and transfers to other institutions. All households pay tax, realize transfers and save according to fixed shares of income. Households purchase marketed commodities according to a linear expenditure system (LES).

Government revenues come from taxes paid by economic activities, capital and other transfers realized by institutions. These revenues are allocated to public spending, transfers and savings. The amount of public spending by product after the simulation is adjusted from the multiplication of the base year quantity by the adjustment factor. Similarly, investment is defined as the base year quantity multiplied by an adjustment factor.

Direct and indirect emissions of economic activities and household's emissions are considered in the AGEM. Direct emissions of household (EDH) refer to those resulting from energy consumption, such car use, heating, cooking...etc. In the AGEM, these emissions can be expressed as the emissions per unit of income (I) multiplied by the income of household (Y).

$$EDH = Y.\, I$$

The direct and indirect emissions of economic activities are those that occur during the production process or treatment of a product. These emissions are associated with the household's consumption, NPI, government, investment and export, and are determined by the environmentally extended input–output analysis.

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

where EA (1×26) is the vector of direct and indirect emissions of economic activities (in thousand tons of CO_2 equivalents) d, (1×26), vector of coefficients of emission (in physical units) per unit of each account resources, $(I\text{-}A)^{-1}$, (26 x 26) is the Leontief inverse matrix, with **A**, (26 x 26), a matrix of technical coefficients corresponding, and **I** is an identity matrix. **S**, (26x26), is the diagonal matrix of final demand.

In the analysis, direct and indirect emissions after chocks are calculated from a new technical coefficients matrix $\mathbf{A_1}$ and a new final demand $\mathbf{S_1}$, while the unit vector d remains constant.

The following expression summarizes the total emissions produced in Aragon.

$$ET = EDH + EDIA.$$

Where ET, are the total emissions and EDIA, are direct and indirect emissions generated in all productive activities (EDIA = Σ_a EA).

The IFPRI model includes three macroeconomic balances: Balance of foreign trade, balance of government and the savings-investment balance. Decisions regarding these balances are known as closure rules and are required to maintain the equilibrium of the model. According to the issues addressed in this paper, what follow are the closure rules considered in the model.

Changes in private consumption preferences consist in assuming that all classes of household have a similar consumption pattern. This homogenization means that the saving in the consumption of a determinate good increases consumption of other goods without changing household expenditures. To make this assumption in the AGEM, household incomes, marginal propensity to save and transfers rate of domestic institutions (households, NPI and societies) are kept constants. Furthermore, in order to maintaining household expenditures constants, we assume that government saving is flexible, which implies that the size of public sector (measured by government expenditure) is fixed. In respect to the foreign balance, it is assumed that exchange rate is endogenous and net foreign saving is constant, while in the savings-investment balance, the quantities of investment remain fixed. Both rules make that the new investments account is adjusted to the new savings account from the Financing capacity/requirement.

Improvement in technological efficiency is implemented in the model as 5% savings of inputs in the major three polluting activities, inputs are referred to: intermediate goods and primary factors. In these simulations, government saving is endogenous; investment and exchange rate are kept fixed. Similar closure rules are applied when tax on emissions (5 € / thousand tons of CO_2 equivalents) is introduced in the AGEM, but additional fiscal revenues are allocated to the government expenditure, so government saving is kept constant.

When simulation is introduced to the AGEM, the resulting changes in emissions and economic variables are reported in terms of the percentage change from the base year values given by the SAMA-05.

3. Baseline scenario

Using the information contained in the SAMA-05, GHG emissions account and input-output model, we obtain a basic description of GHG emissions structure of the Aragonese economy. According to the Table A2, we can see that four economic activities cover over 90% of GHG emissions in Aragon. Emissions derived from "Energy", "Non-metallic and mineral products" and "Paper, publishing and printing" are mainly CO_2 emissions, representing respectively 60,14%, 7,11% and 6, 84% of the total emissions of this gas in Aragon, while emissions of agricultural activities are mainly generated in N_2O (93,32%) and CH_4 (81,82%).

Emission values[4] obtained indicate that with an increase of 1 euro in final demand, GHG emissions increase with an average of 0,58 kg of CO_{2eq}. The greatest effect is observed in the energy sector, followed by "Agriculture, forestry and aquaculture", "Paper, publishing and printing", "non-metallic and mineral products", "Water" and "Food, beverages and tobacco". We can see also that all services activities except "Transport and communications" have a low emission values.

Based on the input-output model, it is possible to distribute GHG emissions of economic activities between components of final demand. This deal allows knowing the environmental impact of each institution in total GHG emissions generated in economic activities. As it is shown in Table 1, emissions associated to exports are the most important in Aragon, representing 47,24% of emissions of economic activities, whereas 35,82% of these emissions are attributed to the private consumption, which corresponds to 17,01 tons of CO_2 equivalents per household. By adding this quantity to the direct emissions of households (1581 thousand tons of CO2 equivalents), we find that total emissions of households represent 31,85% of GHG emissions in Aragon, which 7618 thousand tons of CO2 equivalents are indirect (82%).

The structure of emissions associated to each institution presented in the Figure 1, indicates that emissions associated to household are mainly due to the consumption of "Energy", "Agriculture and Food" and other services (especially business services and real estate). In this case, emissions associated to industrials products do not seem to be very significant (2,61%), and the high participation of services is due to the volume of household expenditure, which influences are rather than their emission potential. However, industrials products have a higher participation in emissions associated to export; together with "Agriculture and Food" and "Energy" they totalize more than 75% of these emissions. Unlike private consumption and export, the emissions of NPI and government are mainly originated from one aggregate product group "Services". Investment emissions are mostly due to "Construction".

Analyzing these emissions by household income class, we see that GHG emissions begin to increase until the forth income interval (1500-2000 euro) and go back down in the interval of income (2500-3000 euro). One more time, emissions rise in the interval (3000-5000 euro) to lower finally, when the monthly income exceeds 5000 euro. These differences observed can be attributed to the superposition of emission

[4] $\lambda = d\,(\mathbf{I}-\mathbf{A})^{-1}$

intensity, number of households in each income class and the average of household expenditure.

The emission intensity is defined as the level of GHG emissions per unit of household expenditure, reflecting how consumption pattern affect emissions associated to household. The average emissions intensity, presented in the table 1, is obtained by dividing emissions associated to household by total expenditure for the different household class ordered equivalent income. In general, results show that emissions intensity do not exceed 500 grams per euro for all household classes, and it decreased with income level; except in the case of highest income class (> 5000 euro). This variation in emission intensity is attributed to changes in consumption patterns with increasing incomes.

Table 1.

Figure 1.

Figure 2 shows the structure of expenditures on seven aggregate product groups by equivalent household income class. With increasing incomes, we can observe a change in the consumption pattern. The share of expenditures on "Agriculture and Food" decreases from 17,07 to 8,06% of total expenditures. The share of expenditures on "Energy" and "Construction" decrease moderately from 5,50 to 4,61%, and from 2,68 to 1,80%. By contrast, the share of expenditures on 'Industrials products' increases from 4,24 to 8,82%. Households with high income levels spend more money on "Manufacturing products" (6,69%) than households with low income levels (4,51%). The share of expenditures on "Services" to total expenditures nearly remains constant. So, when the income of the consumer increases, the demand for "Transports and communications" increases. The variation in consumption patterns indicates that environmental impact may change substantially with increasing incomes. In addition, this aggregated vision helps to identify those areas of consumption in which households can make significant contributions to environmental sustainability.

Figure2.

4. Consumption patterns and GHG emissions

The economic effects of changes in consumption patterns (see Table 2) indicate that the GDP increases progressively through homogenizations realized. It starts to grow positively from the simulation (ESH5) and achieves the highest growth in the simulation (ESH8). Otherwise, the three economic variables decrease simultaneously when consumption pattern of low (<1000 euro) and the highest household income (> 5000 euro) are considered in the simulation.

Table 2.

The input-output model of emissions included in the AGM, allows associate the emissions of economic activities to the final demand components. In this sense and in order to analyze the environmental effects of changes in consumption pattern, we proceed to analyze these effects by component of final demand.

From the effects observed in emissions associated to household income classes (see Table 3), we can observe that changes produced have the same structure in all the simulations realized. Such changes can be summarized en: 1). Increase (decrease) in emissions associated to household with higher (lower) income than income of household class considerate in the simulation, and 2). Emissions associated to household confirm the inverse relationship between household income and emision intensity.

Table 3.

Through these homogenizations, we have seen that lowers income levels are associated with high polluting consumption patterns. However, total emissions in Aragon do not follow this rule; we note that total emissions have an inverted U-shape and they start to decrease when households income is higher than 2000€. This result can be explained by changes in exports (represent more than 41% of final demand), public expenditure and investment.

We can see in the Table 4 that homogenization (ESH1) generates the greatest reduction in emissions associated to exports, followed by (ESH8) (ESH2) and (ESH7). In other simulations, emissions increase at a small rate which is less than 2%. Also, slight changes are observed in emissions associated to government expenditure and investment. In terms of total GHG emissions occurred in economic activities, results indicate that when consumption patterns of household class (3000-5000 €) is implemented (ESH7), total GHG emissions are reduced by -1,93%, which is small change compared to -2,48% obtained when consumption patterns, characterized by a lower emission intensity, are considered (ESH8). Similar results were obtained in the simulation (ESH1), here total GHG emissions are reduced by -0.55%. Also, this negative change can be compared to increases obtained when consumption structures applied in the homogenization are more sustainable.

Table 4.

5. Technological change and GHG emissions

Effects of technological efficiency improvements are represented in the Table 5. Results indicate that scenarios implemented have caused growth of GDP and GHG emissions. The higher economic growth is observed when the technological efficiency of “Energy” (ESE2 in the table) is improved, while the largest increase in total GHG emissions is registered when improvement is implemented in “Agriculture, forestry and aquaculture” (ESE1 in the table).

Effects observed can be summarized in that efficiency improvement reduce costs and make some products cheap inputs to produce, spilling over the impact of technological change to other industries which in turn will produce final goods at lower prices. When these products are exported, the lower domestic supply prices make the Aragones exporters more competitive in foreign trade. In contrast, domestic supply prices stimulate domestic purchases and reduce imports. Falls of total exports occurred in ESE1 and ESE2 are mainly due to decreases in the export of “Metal products and machinery" and "Transport equipments" which represent over 52% of total export in Aragon.

Table5.

Increases in total GHG emissions in the three simulations correspond to the emissions of economic activities and direct emissions of households. According to the AGEM, changes in direct emissions of households are identical to changes in household income. Keeping the vector of coefficients of emission per unit of account resources constant, change in GHG emissions of economic activities can be decomposed into two major components: a Leontief inverse effect due to changes in the factor input matrix and a final demand effect attributable to changes in a final demand vector. Okushima and Tamura (2010). An approximation of both effects can be obtained by examining changes in emissions values (proxy of technological effect) and final demand (demand effect) in each simulation. However a simple decomposition[5] is applied here in three economic activities for approximate the force driving of each factor in changes observed. Results are presented in the Table 6.

Emission values of the energetic sector have decreased, which mean that input substitution is realized by changing some product by others less polluting; but it does not contribute significantly to reduce emissions of this sector because falls in prices have stimulate demand effect. Technological change occurred in "Agriculture, forestry and aquaculture" and "Non-metallic and mineral product" do not correspond to "greening process". Following the same approach in all economic activities for the three simulations, we observed that demand effect is the major force that explains increases in emissions.

Table 6.

Simulation of tax on emission was introduced in the AGEM in order to knowing how the incorporation of the environmental cost can stimulate technological changes that reduce GHG emissions. Effects observed are reported in the last column of Table 5 (Ecotax). As it was expected the biggest price effects is observed in the most polluting activities, also slight increases occurred in some services due to the highest public demand. Changes in prices drive to changes in imports and exports. Private consumption increased by 0,50% as a result of increase in household income (0,09%). The providing of the new final demand is realized through imports.

Contrary to other simulations, total GHG emissions of Aragón are reduced by less than 1%. Households' direct emissions have increased by the same rate of income. However decreases registered correspond to reductions in emissions of economic activities. Disaggregated analysis shows that reductions were occurred in seven

[5] Emissions of an economic activity *a* can be represented as: $e_a=\lambda_a s_a$, where λ_a is the emission value of *a* and s_a is the corresponding final demand. Change in emissions of *a* after the simulation can be written as: $e_{a1}/ e_{a0} = \lambda_{a1} s_{a1}/ \lambda_{a0} s_{a0}$. The transformation of variables to logarithms allows determining each components fraction of the total and assures that all factors add to 100%:
$ln\ (e_{a1}/ e_{a0}) = ln\ (\lambda_{a1}/ \lambda_{a1}) + ln\ (s_{a1}/ s_{a1}) \Rightarrow \Delta e_a = \Delta \lambda_a + \Delta s_a$. Similar relationship has been used in Feng et al. (2009).

activities. Same results have been obtained with several tax rate (10-15-20 € / thousand tons of $CO2$ equivalents).

Examining changes in the emission values and final demand at the product level, we can confirm that reduction of emissions observed in “Chemical products” and “Wood and cork” are explained by falls in exports of these products because emissions values have increased. Declines in the emission of the five most polluting activities are attributed to both effects, this mean that technological changes adopted by the major polluting activities correspond to a substitution of some inputs by others less polluting “greening process”. The simplified decomposition shows that in those industries (See Table 7), demand effect still the main driver force in decrease of emissions, while the effect “Cleaner technology” has a secondary role, although it has contributed significantly (over 35%) to decrease emissions in “Food, beverages and tobacco”.

Table 7.

6. Conclusions

In this paper we analyzed the Aragon GHG emissions using an Applied General Equilibrium Model. Our interest was to evaluate the effects of changes in consumption patterns and determine how technological changes can contribute to the reduction of GHG emissions.

From the results of consumption analysis, it should be noted that total GHG emissions start to decline in Aragon when consumption patterns of households with income more than 2500€ are considered. The absence of a progressive character that corresponds to the relationship household income-emission intensity contrasted in this work is mainly explained by changes in exports. In this sense, it is necessary to include the impact of foreign trade in the analysis of GHG emissions. Munksgaard *et al*. (2001). To complete the objectives of this study, a structural decomposition of effects on exports will help us to explain better results obtained.

Secondly, we confirm that technology efficiency improvements in order to reduce production costs do not always match with a “greening technological process”. Moreover, if this change consists in the substitution of some inputs by others with less potential of emission, emissions of these activities are not reduced due to the demand effect. As the costs function do not include the environmental cost, industries adapt new technology in order to reduce costs, the price of output and improve competitiveness. Under these conditions, the regulation of demand seems to be an efficient strategy to achieve lower emissions but would cause declines in the economic welfare with respect to the initial situation. In contrast, the inclusion of the environmental costs has a restrictive effect, and induces industries to adapt cleaner technologies that limit their environmental impact. However, again we observed that the demand effect still the key factor in the regulation of GHG emissions, i.e. reduction of GHG emissions is achieved by limiting the competitiveness of industries which it often limits economic growth.

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Appendix (A)

Table A1.Social Accounting Matrix for Aragon (SAMA-05)

	Agricultura y alimentac	Energía	Industria	Manufacturas	Construcción	Transportes	Servicios	Trabajo	Capital	H1	H2	H3	H4	H5	H6	H7	H8	ISFLSH	Sociedades	IVA	Impuestos netos	Gobierno	Sector exterior	Ahorro-Inversion	total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	2,754	37	7	153	105	1	1,367	.	.	52	266	404	424	305	214	258	58	.	.	.	.	.	2,430	55	8,890
2	89	315	354	79	46	232	327	.	.	17	76	122	133	108	79	117	37	.	.	.	.	.	544	-0	2,676
3	356	144	7,743	707	1,843	178	1,160	.	.	13	80	171	215	181	138	196	63	.	.	.	.	135	12,020	1,941	27,283
4	79	22	1,044	920	248	44	556	.	.	14	83	154	179	152	117	177	48	.	.	.	.	.	2,434	25	6,294
5	9	37	30	6	651	77	882	.	.	8	35	49	50	40	29	45	14	.	.	.	.	.	2	4,691	6,654
6	87	86	543	134	164	405	719	.	.	12	67	127	148	121	88	131	37	.	.	.	.	1	633	33	3,535
7	219	257	1,508	412	820	564	4,243	.	.	188	921	1,534	1,691	1,397	1,050	1,585	458	169	.	.	.	5,051	1,725	1,314	25,106
8	434	117	2,161	678	1,596	505	6,984	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	12,475
9	1,484	650	1,338	479	1,094	661	5,962	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	11,667
10	.	.	.	.	.	.	.	9	45	.	.	.	.	.	.	.	.	0	16	.	.	19	5	.	95
11	.	.	.	.	.	.	.	428	346	.	.	.	.	.	.	.	.	2	123	.	.	464	39	.	1,402
12	.	.	.	.	.	.	.	2,611	864	.	.	.	.	.	.	.	.	5	306	.	.	939	98	.	4,823
13	.	.	.	.	.	.	.	3,433	1,073	.	.	.	.	.	.	.	.	6	380	.	.	971	122	.	5,985
14	.	.	.	.	.	.	.	2,128	935	.	.	.	.	.	.	.	.	5	331	.	.	561	106	.	4,067
15	.	.	.	.	.	.	.	1,174	754	.	.	.	.	.	.	.	.	4	267	.	.	250	86	.	2,534
16	.	.	.	.	.	.	.	2,560	1,343	.	.	.	.	.	.	.	.	7	476	.	.	546	153	.	5,084
17	.	.	.	.	.	.	.	130	338	.	.	.	.	.	.	.	.	2	120	.	.	28	38	.	657
18	.	.	.	.	.	.	.	.	13	2	14	34	42	36	29	52	13	.	27	.	.	23	12	.	297
19	.	.	.	.	.	.	.	.	5,478	6	29	48	53	43	32	47	13	1	2,471	.	.	506	464	.	9,191
20	4	1	15	4	3	5	236	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	268
21	-263	-62	119	7	79	104	341	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	325
22	.	.	.	.	.	.	.	.	480	57	312	1,245	1,447	1,094	901	1,183	303	1	1,544	268	325	2,404	183	1,138	12,887
23	3,637	1,070	12,421	2,717	4	759	2,331	.	.	38	123	140	124	84	56	68	14	27	1,190	.	.	30	.	-2,647	22,186
24	.	.	.	.	.	.	.	.	.	-311	-601	794	1,479	505	-199	-1,225	401	67	1,939	.	.	961	1,092	.	6,549
25	8,890	2,676	27,283	6,294	6,654	3,535	25,106	12,475	11,667	95	1,402	4,823	5,985	4,067	2,534	5,084	657	297	9,191	268	325	12,887	22,186	6,549	180,931

Table A2. The structure of GHG emissions in Aragon

		Emissions account		Emissions value	Direct and indirect emissions	
Code	**Economic activity**	10^6Kg de CO_{2eq}	%	Kg de CO_{2eq} /euro	10^6Kg de CO_{2eq}	%
1	Agriculture, forestry and aquaculture	5.446	23,84	1,79	2.511	11,81
2	Energy	10.765	47,12	4,70	5.742	27,00
3	Water	84	0,37	0,92	90	0,42
4	Minerals and metals	9	0,04	0,28	27	0,13
5	Non-metallic and mineral product	1.255	5,49	1,06	526	2,47
6	Chemicals products	114	0,50	0,30	379	1,78
7	Metal products and machinery	548	2,40	0,17	923	4,34
8	Transport equipments	486	2,13	0,17	1.325	6,23
9	Food, beverages and tobacco	34	0,15	0,60	1.813	8,53
10	Textile products	4	0,02	0,09	77	0,36
11	Paper, publishing and printing	1.224	5,36	1,16	1.027	4,83
12	Wood and cork	4	0,02	0,36	95	0,45
13	Plastic and other manufacturing products	27	0,12	0,18	239	1,12
14	Construction	112	0,49	0,35	1.729	8,13
15	Recycling	0	0,00	0,20	19	0,09
16	Commercial services	290	1,27	0,37	1.266	5,95
17	Hotels and restaurants	58	0,25	0,31	604	2,84
18	Transport and communications	375	1,64	0,56	773	3,63
19	Credits and Insurances	10	0,05	0,18	101	0,47
20	Real estate	-	-	0,11	436	2,05
21	Private education	7	0,03	0,22	53	0,25
22	Private health	12	0,05	0,22	69	0,33
23	Other sales-oriented services	269	1,18	0,21	358	1,68
24	Public education	1	0,00	0,08	52	0,25
25	Public health	12	0,05	0,14	201	0,95
26	public services	119	0,52	0,30	831	3,91
H1	< 500 €	15	0,06	-	-	-
H2	500-1000€	152	0,66	-	-	-
H3	1000-1500€	342	1,50	-	-	-
H4	1500-2000€	375	1,64	-	-	-
H5	2000-2500€	330	1,45	-	-	-
H6	2500-3000€	198	0,87	-	-	-
H7	3000-3500€	155	0,68	-	-	-
H8	>5000€	14	0,06	-	-	-
	Average	-	-	0,58	-	-
	Total	22.847	100,00	-	22.847	100,00

Appendix (B): system equations of the AGEM

1. Production

At the top of technology nest

$$QA_a = CES\ (QINTA_a, QVA_a), \text{ for the most polluting industries}$$

$$QA_a = f\ (QINTA_a, QVA_a)$$

At the second of technology nest

$$QVA_a = CES\ (L, K), \text{ for the most polluting industries}$$

$$QVA_a = iva_a .\ QA_a$$

$$QINTA_a = inta_a .\ QA_a$$

2. Foreign trade

Armington Function Φ

$$QQ_C = \Phi\ (QM_C, QD_C)$$

Constant Elasticity of Transformation (CET) function

$$QX_C = CET\ (QD_C, QE_C)$$

3. Institutions

Income of domestic institutions *i* (Household, NPI and Societies)

$$YI_i = YIF_i + TRII_i + TRG_i.CPI + TRE_i.\ EXR$$

Expenditures of domestic institutions *i*

$$GI_i = EH_h + EH_s + EMi + S_i$$

$$EH_h = YI_h - (EM_h + S_h)$$

Private consumption by product *c*,

$$PQ_c .QH_{c,h} = PQ_c .\ \gamma_{c,h} + \beta_{c,h} .\ (EH_h - \sum PQ_C .\ \gamma_{c',h})$$

Government balance

$$YG = EMi + YGK + YGI + \sum tva_a .\ PVA_a .\ QVA_a + \sum ta_a .\ PA_a .\ QA_a + \sum te_a .\ w_a .\ QA_a$$

$$GE = \sum PQ_C .\ QG_c + TRG_i .CPI + GSAV, \text{ con: } QG_c = QG_{c0} .\ GADJ$$

Foreign balance

$$YF=\sum Pm.\ QMc+ CNF$$

$$GF=\sum Pe.\ QEc + TRE_i.\ EXR+ FSAV$$

Saving-Investment balance

$$S=S_i+ GSAV+ FSAV$$

$$I=\sum PQ_C.\ QINV_c+ YGI+ CNF,\ con:\ QINV_c= QINV_{c0}.\ IADJ$$

Variables

CNF: Financing capacity/requirement
CPI: Consumer price index
EH_h: Household expenditure for household *h*
EH_s: Consumption of NPI
EM_i: Transfers of institutions to government (tax and other items)
EXR: Exchange rate
I: Total investment
IADJ: Investment adjustment factor
K: Capital factor
L: Labour factor
FSAV: Foreign net saving expenditure
GADJ: Government consumption adjustment factor
GE: Government expenditure
GF: Foreign expenditure
GI_i: Expenditures of domestic institutions *i*
GSAV: Government saving
PA_a: Activity Price
PE_c: Export price of *c*
PM_c: Import Price of *c*
PQ_c: Price of composite good *c*
PVA_a: Price of aggregate value-added
QA_a: Quantity (level) of activity
QD_C: Quantity of domestic sales
QEc: Quantity of export of *c*
QG_c: Government consumption demand for commodity
QG_{c0}: Base-year quantity of government demand
$QH_{c,h}$: Quantity of consumption of *c* for household *h*
QINTAa: Quantity of aggregate intermediate input
$QINV_c$: Quantity of fixed investment demand for commodity
$QINV_{c0}$: Base-year quantity of fixed investment demand for commodity
QMc: Quantity of import of *c*
QQ_C: Quantity of composite goods supply
QVAa: Quantity of aggregate value-added
S_i: Saving of domestic institutions *i*.

S: Total saving
TRE_i: Transfers from foreign sector to *i*
TRG_i: Transfers from government to *i*
TRIIi: Infra-institutional transfers
YF: Foreign sector income
YG: Government Income
YGI: Tax on capital
YGK: Factor income of government
YI_i: Income of domestic institutions *i*
YIF_i Factor income of *i*

Parameters

$\gamma_{c,h}$: subsistence consumption of *c* for household *h*
$\beta_{c,h}$: Marginal share of consumption of *c* for household *h*
$inta_a$: Quantity of aggregate intermediate input per activity unit
iva_a: Quantity of value-added per activity unit
ta_a: Tax rate for activity
te_a: Emission tax rate
tva_a: Rate for value-added tax for activity *a*
w_a: Emission per activity unit

Tables:

Table 1

	Emissions	Percentage	Household expenditure	Emissions intensity	Number of household
Unity	10^6 Kg	%	Euros	gram of CO_{2eq} /Euro	Household
< 500 €	170	0,80	11.906	559	25.466
500-1000€	833	3,92	18.006	546	84.759
1000-1500€	1.370	6,44	26.328	535	97.305
1500-2000€	1.507	7,09	32.887	531	86.348
2000-2500€	1.206	5,67	39.385	523	58.509
2500-3000€	887	4,17	44.407	517	38.613
3000-3500€	1.276	6,00	53.079	509	47.268
>5000€	369	1,74	74.663	517	9.560
Export	10.047	47,24	-	508	-
Other institutions	3.601	16,93	-	268	-
Total	21.266	100,00	-	-	447.827

Emissions associated to each component of final demand

Table 2

Simulation	GDP	Production	Import	Export
ESCH1	-0,37	-1,13	-3,71	-3,69
ESCH2	-0,36	-0,27	-0,88	-0,82
ESCH3	-0,17	0,27	0,82	0,91
ESCH4	-0,05	0,51	1,57	1,69
ESCH5	0,07	0,29	0,85	0,90
ESCH6	0,13	0,13	0,41	0,39
ESCH7	0,28	-0,61	-1,84	-2,05
ESCH8	0,44	-0,86	-2,75	-2,87

Economic effects of change in consumption patterns

Table 3

Simulation	H1	H2	H3	H4	H5	H6	H7	H8	Households
ESH1	0,00	2,33	4,44	5,25	6,73	7,89	9,79	7,91	44,34
ESH2	-2,29	-0,00	2,09	2,89	4,35	5,49	7,36	5,54	25,44
ESH3	-4,32	-2,07	-0,00	0,80	2,25	3,37	5,22	3,46	8,72
ESH4	-5,11	-2,88	-0,81	0,00	1,44	2,56	4,41	2,67	2,29
ESH5	-6,47	-4,27	-2,22	-1,43	0,00	1,10	2,93	1,22	-9,14
ESH6	-7,50	-5,32	-3,29	-2,50	-1,09	0,00	1,81	0,13	-17,79
ESH7	-9,15	-7,01	-5,01	-4,23	-2,85	-1,77	0,00	-1,65	-31,67
ESH8	-7,62	-5,44	-3,41	-2,62	-1,21	-0,12	1,68	-0,00	-18,75

Effects of change in consumption pattern on emissions associated to households.

Table 4

Simulation	Export	Government	Investment	Total Emissions
ESH1	-5,69	- 0,25	-0,12	-0,55
ESH2	-1,91	-0,12	-0,02	0,39
ESH3	0,63	-0,03	0,01	0,89
ESH4	1,95	0,01	0,00	1,23
ESH5	1,10	0,03	0,01	0,30
ESH6	0,93	0,05	0,01	-0,17
ESH7	-1,48	0,05	0,02	-1,93
ESH8	-3,79	-0,03	-0,11	-2,48

Effects on emissions associated to exports, government expenditure, investment and total emissions of industries

Table 5

Magnitude	ESE1	ESE2	ESE3	Ecotax
GDP	0,57	0,60	0,45	0.02
Production	-1,27	-0,52	-0,03	-0.05
Import	-3,00	-1,26	-0,24	0.03
Export	-3,02	-1,90	0,35	-0.64
Government	-0,78	0,14	0,08	1.29
Investment	0,30	0,20	-0,31	-0.04
Private consumption	0,45	1,42	-0,55	0.50
Household emissions	0,26	0,75	-0,14	0,09
Industry emissions	6,04	2,45	0,50	-0,87
Total GHG Emissions	5,64	2,33	0,45	-0.81

Technological changes and emissions

Table 6

Simulation	Industry	Δ s	Δ λ	Change
ESE1	Agriculture, forestry and aquaculture	98,06	1,94	56,58
ESE2	Energy	100,18	0,18	15,99
ESE3	Non-metallic and mineral product	91,25	8,75	37,16

Effects of technological efficiency improvements

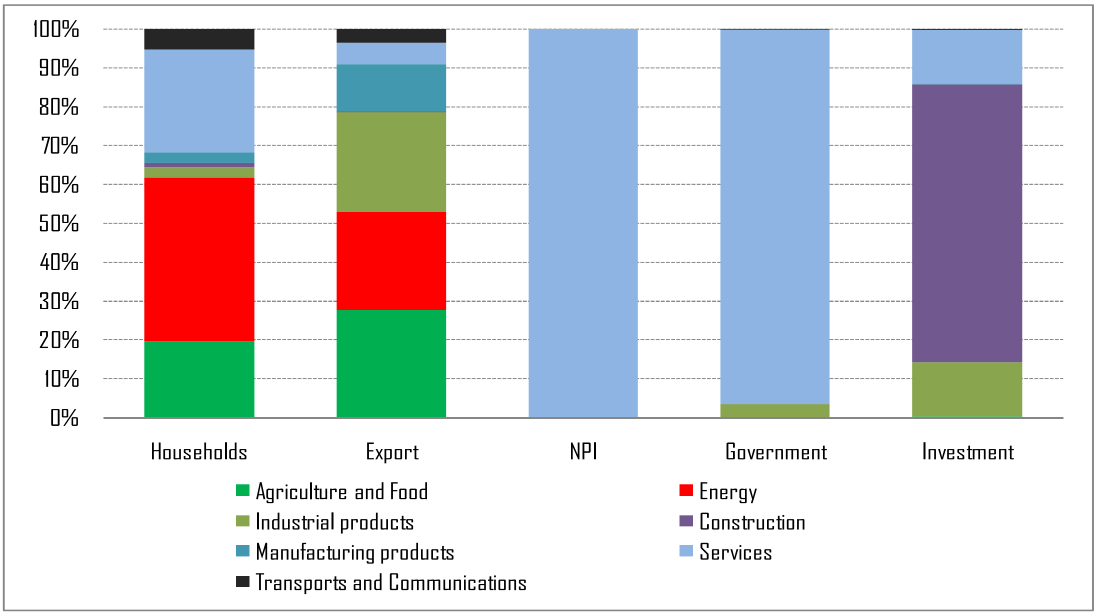
Table 7

Industry	Δ s	Δ λ	Change
Agriculture, forestry and aquaculture	94,26	5,74	-2,11
Energy	89,78	10,22	-2,64
Non-metallic and mineral product	95,66	4,34	-2,32
Food, beverages and tobacco	56,89	43,11	-0,49
Paper, publishing and printing	93,09	6,91	-4,32

Technological effect and demand effect in the reduction of GHG emissions

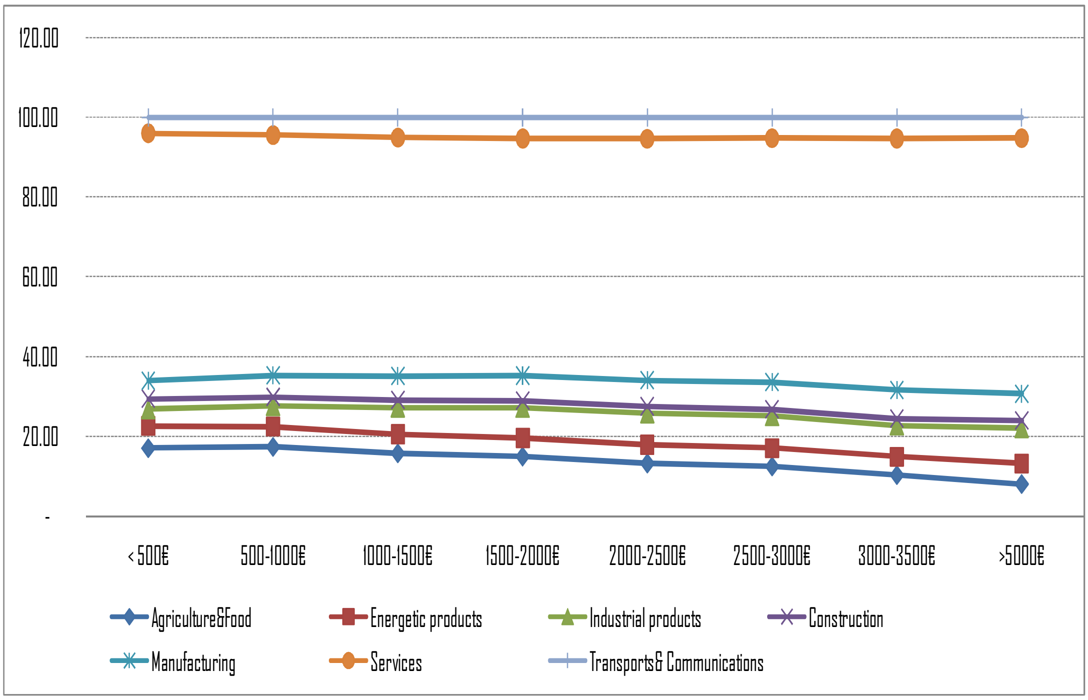
Figures:

Figure 1



Structure of GHG emissions by product groups

Figure 2



Structure of consumption by household income class