Distortionary effects of environmental taxes in a regional economy: an applied general equilibrium model of the Andalusian economy

Polo, Clemente [a]; Cardenete, M. Alejandro [b]; Fuentes-Saguar, Patricia D.*[c];

[a] Departamento de Economía
Universidad Autónoma de Barcelona, Spain
E-mail: polo.clemente@uab.es

[b] Departamento de Economía
Universidad Pablo de Olavide
E-mail:macardenete@upo.es

[c] Departamento de Economía
Universidad Pablo de Olavide
Ctra. de Utrera, Km.1, 41013, Sevilla, Spain
Phone 0034 954348995. E-mail: pfuesag@upo.es

*Corresponding author

Abstract

The goal of this paper is to quantify the effects of an environmental fiscal reform in Andalusia, the largest and most populated region of Spain, on CO_2 emissions, production levels and the welfare of a representative household. The proposed fiscal reform would introduce a tax on fossil fuels responsible for CO_2 emissions (ET tax). The Applied General Equilibrium (AGE) model has been calibrated using a social accounting matrix (SAMAND-00) constructed by the authors for the year 2000. The model allows for substitutability among energy factors, as well as between energy and non energy factors. It also includes a real wage-unemployment equation that captures labor market frictions that may result in a variable unemployment rate. The effects of the introduction of the environmental tax have been counteracted by an appropriate reduction in direct (income) or indirect (labor) tax rates to keep government revenue constant. The results obtained indicate that, the low revenue capacity of the environmental tax notwithstanding, the introduction of the ET lowers production levels and welfare, even when those revenues are applied to lower the labor tax rate.

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1. INTRODUCTION

The concepts of environmental pollution and negative externality, or market failure, are not new, and these concepts have given rise to the claim that environmental taxes are necessary to internalize external costs related to the environment.

David Pearce (1991) articulated the hypothesis of the double dividend of environmental taxation, with which non-environmental objectives can be pursued through green tax reform, and his hypothesis became the basis of academic proposals for such reforms (Rodriguez, 2002).

In the early nineties, northern European countries such as Germany began to implement taxes designed to reduce emissions, alongside reductions in other taxes to offset a loss in employment. This is known as "environmental" or "green" tax reform.

Until now, economic research on environmental fiscal reform from both theoretical and applied approaches has mainly focused on uncovering the circumstances under which the double dividend emerges. The question of whether to implement tax reforms that benefit the environment depends on whether such benefits are offset by economic costs in terms of output, inflation, or non-environmental welfare. This can be measured through a cost-benefit analysis, but such analyses are inconvenient due to the difficulty of measuring environmental benefits.

Since the Stern Report[1], there has been a gradual change in the way economists deal with these issues. The report points out, as seen in previous studies, that controlling the volume of greenhouse gas emissions is probably the most important economic challenge facing humanity in the coming decades. Such emissions must be controlled if we are to

[1] Stern (2006) demonstrates in his report that the cost of reducing emissions is considerably less than the expenditure that would be needed to mitigate the damage.

avoid serious and irreversible damage to both humans and the environment in the second half of the twenty-first century. To avoid such damage, the report suggests a number of measures, including setting a price on emissions of CO_2. This price, Stern says, can be defined explicitly as a tax.

Although the Stern Report makes it clear that environmental fiscal reforms are justified in themselves, the challenge remains of how best to implement such reforms. Furthermore, if the implementation of such reforms creates a double dividend, then we will realize improvements in not only environmental but also non-environmental welfare.

Today, many economic studies have been developed on energy and the environment, including aspects such as climate. Many such works assess the economic impact of energy policies and environmental models using the Computable General Equilibrium or Applied General Equilibrium (AGE). The first of these was performed by Bovenberg and Mooij (1994) and, following their example, Manresa and Sancho (2005), Rodriguez (2003), Gomez et al. (2003) and others have used similar models in studies of policy in Spain.

Recent studies have applied general equilibrium models to policy in regional areas of Spain. These include a study by Gonzalez and Dellink (2006) focusing on Basque Country and the work of André, Cardenete and Velázquez (2005), who assess the impact of a particular environmental tax reform on the economy of Andalusia.

Our work continues along the same line as that of André et al. (2005) with some differences as the treatment of energy. The aim of our research is to analyze the effects of an environmental tax reform on Andalusia. To do so, we simulate the distorting effects on the Andalusian economy caused by an environmental tax on CO_2 emissions generated by production activities that is understood as a "price" for such emissions, as recommended by Stern (2006).

We compare two simulations of the effects of this tax reform. The first simulation allows us to estimate the pure economic effects of imposing a tax on CO_2 emissions from energy consumption. The second simulation estimates the economic effects when this tax increase is paired with a reduction in contributions to Social Security (payroll taxes). This comparison will allow us to assess the conditions necessary for a realization of the so-called double dividend from this environmental tax.

To this end, we present an applied general equilibrium model (AGEAND-00) that we use to simulate the Andalusian economy using data from the year 2000. The model parameters are obtained from a calibration using the SAMAND00, which distinguishes five energy goods. Emissions are derived from vector C[2], presented in the appendix, and the Emission Inventory of Andalusia (2003).

The paper is divided into four sections. In the second section, we describe AGEAND-00, including environmental accounts. In the third section, we describe the calibration process and balance the model. In the fourth section, we present the simulations and their results. The last section summarizes the main findings of this research and presents possible extensions of the research.

2. AN APPLIED GENERAL EQUILIBRIUM MODEL FOR THE ANDALUSIAN ECONOMY

An AGE model can be defined as a set of numerical equations that represent the environment and behavior of agents in a virtual economy. The result is a replicated

[2] The vector C transforms the monetary unit of SAMAND00 emission into physical units.

database of the economy to which it applies. In this section, we present a static AGE for the Andalusian economy (AGEAND-00) inspired by the canonical Walrasian model developed by Showen and Whalley (1992). The model developed here is simple and should be taken as a first step in a direction that this research will focus on the immediate future.

The model includes four types of agents: 15 producers, a representative consumer, the government and an external sector. Also included are factors of production (labor and capital) and four taxes, two direct and two indirect. In addition, the model includes the introduction of an environmental tax levied on purchases of energy goods responsible for CO_2 emissions.

Some variables are assumed to be fixed (exogenous) as the level of transfers and public sector demand for public spending, which is usually determined by political decisions, and the level of external transfers and the level of exports, both of which depend on the world economy. Other variables, such as relative prices, the government deficit, and productive sectors, are assumed to be endogenous variables.

An equilibrium of the economy is a vector of prices for all goods and services and factors, such as production plans and consumption and savings plans, that the consumer maximizes his utility, the productive sectors maximize profits, government revenues equal the sum of all revenues collected and the amounts offered are equal to those demanded in all markets. We will now describe in greater detail the structure of the model.

Production

The model includes 15 productive sectors[3], including sectors 2, 3, 5, 6 and 7, which correspond to the energy sectors of coal, crude petroleum and natural gas, refining oil, electricity and gas manufacturing; other sectors are non-energy goods or services.

Producers used a nested technology with constant returns to scale as defined by the Cobb-Douglas function (CD), or with fixed (or Leontief) coefficients (L), at different levels of the nesting function (Figure 1).

The roles of demand factors and the supply of goods for enterprises are obtained from the maximization of profit subject to technology constraints, the minimization of costs provide such functions, and the condition price equal to the average cost let us to obtain the prices of added products.

(FIGURE 1: The nested production function)

Starting at the last level of nesting, the energy factor (E_j) is defined as a Cobb-Douglas combination of the five energy goods (*E1* to *E5*, which correspond to sectors 2, 3, 5, 6 and 7, respectively) so that its application would be defined as

$$\min \; PE1_j \cdot E1_j + PE2_j \cdot E2_j + PE3_j \cdot E3_j + PE4_j \cdot E4_j + PE5_j \cdot E5_j \quad j=1,\ldots,15. \quad (1)$$

$$\text{s.t.} \quad E_j = \rho 1_j \left(E1_j^{\beta 1_j} \cdot E2_j^{\beta 2_j} \cdot E3_j^{\beta 3_j} \cdot E4_j^{\beta 4_j} \cdot E5_j^{\beta 5_j} \right) \quad j=1,\ldots,15. \quad (2)$$

PE_j is the factor E_j price[4], $PE1_j$ is the factor $E1_j$ price, $PE2_j$ is the factor $E2_j$ price, $PE3_j$ is the factor $E3_j$ price, $PE4_j$ is the factor $E4_j$ price, and $PE5_j$ is the factor $E5_j$ price; $\rho 1_j$ is the scale parameter, and $\beta 1_j$ to $\beta 5_j$ are the share parameters for each of the five energy good.

[3] It is assumed that each sector gets a homogeneous good or service.

[4] The prices of the five energy goods correspond with the final prices of the assets of these accounts (2, 3, 5, 6 and 7).

Furthermore, in order to satisfy the profit maximization model, we must impose the condition that the price must be equal to average cost:

$$PE_j \cdot E_j = PE1_j \cdot E1_j + PE2_j \cdot E2_j + PE3_j \cdot E3_j + PE4_j \cdot E4_j + PE5_j \cdot E5_j \qquad \text{j=1,…,15.} \quad (3)$$

Moreover, the aggregated factor KL_j is generated by the primary factors K_j (capital) and L_j (labor) through a Cobb-Douglas technology, the claims of which are defined as

$$\min \quad PK_j \cdot K_j + PL_j \cdot L_j \cdot (1 + tl_j) \qquad \text{j=1,…, 15,} \quad (4)$$

$$\text{s.t.} \quad KL_j = \rho_j \left(L_j^{\beta_j} \cdot K_j^{1-\beta_j} \right) \qquad \text{j=1,…, 15,} \quad (5)$$

and through the condition to maximize profit,

$$PKL_j \cdot KL_j = PK_j \cdot K_j + PL_j \cdot L_j \cdot (1 + tl_j) \qquad \text{j=1,…, 15,} \quad (6)$$

where PKL_j is the price of the KL_j aggregated factor, PK_j is the price of capital K_j, and PL_j the price of labor L_j. tl_j is the payroll tax rate for contributions paid by employers. ρ_j is the scale parameter, and β_j is the parameter for participation.

In turn, the addition KLE_j is a Cobb-Douglas technology of aggregated KL_j and energy E_j, where the problem of minimizing the cost would be defined as

$$\min \quad PKL_j \cdot KL_j + PE_j \cdot E_j \qquad \text{j=1,…, 15,} \quad (7)$$

$$\text{s.t.} \quad KLE_j = \rho 2_j \left(KL_j^{\delta_j} \cdot E_j^{(1-\delta_j)} \right) \qquad \text{j=1,…, 15,} \quad (8)$$

and the condition of profit maximization as,

$$PKLE_j \cdot KLE_j = PKL_j \cdot KL_j + PE_j \cdot E_j \qquad \text{j=1,…, 15.} \quad (9)$$

$PKLE_j$ is the price of aggregate KLE_j factor, where $\rho 2_j$ is the scale parameter, and δ_j is the participation parameter.

Domestic production of sector *j*, denoted as YD_j, is obtained as a Leontief combination of no-energy intermediate consumption CI_j and aggregated KLE_j. Y_{ij} is the use of each no-energy intermediate i needed to produce good *j*.

The a_{ij} constants are the elements of the matrix of the intermediate coefficient of the SAMAND00 that show the needs of industry *i* necessary to produce one unit of *j*. In the same way, the coefficients v_j are the needs of the aggregate capital, labor and energy required to produce one unit of *j*.

$$YD_j = min\left(\frac{Y_{1j}}{a_{1j}}, \frac{Y_{2j}}{a_{2j}}, \ldots, \frac{Y_{10j}}{a_{10j}}, \frac{KLE_j}{v_j} \right) \qquad j=1, \ldots, 15. \qquad (10)$$

$$PD_j \cdot YD_j = \sum_{i=1}^{10} p_j \cdot a_{ij} + PKLE_j \mathbf{v}_j \qquad j=1, \ldots, 15. \qquad (11)$$

Finally, the total output of sector *j*, at the first level of nesting, where all output sector *j*, Y_j, is obtained as a Cobb-Douglas combination of domestic output YD_j and imports M_j (adopting the Armington[5] hypothesis "that domestic goods and imports are imperfect substitutes"), with λ_j as the scale parameter and $\rho 3_j$ as the participation parameter, according to the following functions:

$$\min \quad YD_j \cdot PD_j + PRM_j \cdot M_j \qquad j=1,\ldots, 15. \qquad (12)$$

$$\text{s.t.} \quad Y_j = \rho 3_j \times YD^{\lambda_j}{}_j \times M_j^{(1-\lambda_j)} \qquad j=1,\ldots, 15. \qquad (13)$$

The producer in this level of nesting minimizes cost, subject to the restriction of the function of total output. In addition, the producer wants to maximize the benefit obtained, so that the model imposes the condition that the price must be equal to average cost; thus,

$$p_j \cdot Y_j = (1+t_j) \cdot (1+ti_j) \cdot (YD_j \cdot PD_j + PRM_j \cdot M_j) \qquad j=1,\ldots, 15. \qquad (14)$$

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[5] Armington (1969).

p_j is the price of final output of sector j, ti_j is the net indirect tax rate on production and imports, and t_j is the environmental tax rate, both taxes defined for each branch.

External Sector

The model assumed a small open economy where prices of goods and services in international markets (PRM_j) are constant and hence the supply of imports is perfectly elastic. The model considers also exogenous exports (EX_j), as well as transfers from abroad (TRM), and endogenous imports (M_j) and the balance of the external sector (SE). The equation for this sector is

$$SE = \sum_{j=1}^{15} PRM_j M_j - TRM \cdot IPC - \sum_{j=1}^{15} EX_j \cdot p_j / (1 + t_j) \qquad (15)$$

where PRM_j represents prices in the rest of the world. Note that the environmental tax does not tax the exports, which are exempt from environmental taxes.

Consumption

Our model assumes a single representative consumer, who receives his income from wages as payment for his work (PL) and the remuneration of capital (PK). Additionally he receives transfers from the public sector and sectors abroad. Gross income (RB) is received by our consumers as

$$RB = PL \cdot L + PK \cdot K + IPC \cdot TSP + IPC \cdot TRM \qquad (16)$$

Moreover, our consumers must pay Social Security and personal taxes (ID). Therefore, disposable income (RD) is

$$RD = (1 - td) \cdot (PL \cdot L + PK \cdot K + IPC \cdot TSP + IPC \cdot TRM) \qquad (17)$$

The role of consumer demand is obtained by maximizing its utility subject to the restriction of disposable income, using a Cobb-Douglas type as a combination of consumer demand DC_j and savings demand (DS).

$$\max \qquad U(DC_i, DS) = \left(\prod_{i=1}^{15} DC_i^{\alpha_i} \right) DS^{\left(1-\sum_{i=1}^{15} \alpha_i\right)} \tag{18}$$

where α_i and ($1-\sum_{i=1}^{15} \alpha_i$) are the coefficients of both DC_j and DS. The goal here is to maximize consumer utility subject to the restriction of disposable income. In turn, disposable income is distributed as follows:

$$RD = \sum_{i=1}^{15} p_i \cdot DC_i + IPI \cdot DS \tag{19}$$

The *IPI* is the price index of investment.

Savings and Investment

In this model, investment value is determined by the sum of private savings, the budget surplus and the balance of the foreign sector:

$$IPI \cdot INVT = DS \cdot IPI + SP + SE \tag{20}$$

where *INVT* is the total investment. The demand for investment to all sectors of production (INV_j) is determined using the coefficients defined by the shares of each sector, COI_j, in the total investment in the base year.

$$INV_j = COI_j \cdot INVT \qquad j=1,\ldots, 15 \tag{21}$$

Emissions and environmental taxes

Emissions are calculated using the vector of emissions per unit of expenditure, calculated for the three energy goods responsible for CO_2 emissions (or at least the main responsible), coal, gas and refining, shown in Table 2 of the appendix. For each sector of production, emissions are obtained by multiplying these ratios by the quantities of energy used in production.

In the model, the use of energy goods causing emissions is taxed proportionally to the intensity of emissions. This raises the price of goods that cause emissions, but also the price of other goods that use these energy assets in its production. The tax rate is determined in two stages, with the purpose of levying higher taxes on higher energy goods whose use generates more emissions, thereby raising their relative price and discouraging their use. First, the model determines a relative index of emissions:

$$\tau_j = \frac{c_j}{c_2 + c_5 + c_7} \qquad \text{j=2, 5 and 7} \qquad (22)$$

where c_j is the coefficient of emissions of the three energy goods that cause emissions, coal, gas and refining, which correspond to accounts 2, 5 and 7 in the model. For the other energy goods, petroleum and electricity assets, which correspond to accounts 3 and 6 in the model, $\tau_j = 0$. We then rescale the index by multiplying by a positive number less than 1, ε, which provides the tax applied to each sector as follows:

$$t_j = \varepsilon \, \tau_j \qquad \text{j=1, 2,…, 15.} \quad (23)$$

Raising the environmental tax ($ECOTS_j$) in each sector can be calculated by multiplying this tax by the value of the consumption of polluting energy goods net of the environmental tax:

$$ECOTS_j = t_2 \cdot \frac{E1_j \cdot PE1}{(1+t_2)} + t_5 \cdot \frac{E3_j \cdot PE3}{(1+t_5)} + t_7 \cdot \frac{E5_j \cdot PE5}{(1+t_7)} \qquad \text{j=1,…, 15.} \quad (24)$$

The environmental tax is also levied on final demand[6], and the collection in this case[7] is

[6] Only the demand for consumption and investment goods consumes energy, because there is no public consumption of these goods and, as already mentioned, the export environment is not taxable.

$$ECOTD = \sum_j t_j \cdot (DC_j + INV_j) \cdot p_j / (1 + t_j) \qquad j=2,\ 5\ y\ 7. \quad (25)$$

The total collection is obtained by adding the total revenues and sectoral final demand:

$$ECOT = ECOTD + \sum_{j=1}^{15} ECOTS_j \quad (26)$$

Public Sector

The public sector collects direct (*ID*) and indirect (*RIIT*) taxes and uses that income to finance their purchases of goods and services, GP_j, and transfers to private agents (*TSP*). *SP* denotes the final balance (surplus) of the public budget:

$$SP = ID + RIIT - TSP \cdot CPI - \sum_{j=1}^{15} GP_j \cdot p_j \quad (27)$$

$$ID = td \cdot RB \quad (28)$$

$$II_j = ti_j \cdot (YD_j \cdot PD_j + PRM_j \cdot IM_j) + tl_j \cdot L_j \cdot PL + ECOTS_j \qquad j=1,\ldots,15 \quad (29)$$

where *CPI* is the Consumer Price Index and p_j is the final price of production of sector *j*. The indirect tax revenue by sector includes the environmental tax levied on the branches of production ($ECOTS_j$).

The parameters *td*, ti_j, and tl_j are the direct, indirect and payroll rates, respectively. The latter is considered variable when the collection is recycled from the environmental tax.

The total indirect tax collection (*RIIT*) is attributable to what is gained from raising taxes on production, changes in social contributions and the tax environment in all sectors and the effect of raising the environmental tax levied on final demand.

[7] The tax applied to the final demand and productive sectors is the same in this model because we assumed that the total final price of the product is the same as the sum of the various components of final demand, despite the fact that there is actually a difference in prices of energy goods, which are often more expensive for the final demand than for their use as intermediate consumption.

$$RIIT = \sum_{j=1}^{15} II_j + ECOTD \tag{30}$$

The levels of public consumption and transfers remain constant, but are not the expenditure that depends on prices. The budget surplus intended to supplement private savings and to finance investment.

3. CALIBRATION

We use the usual calibration procedure to obtain the value of the model parameters. This requires a database, which in this case is the SAMAND00 in its short version, consisting of twenty-five accounts, including fifteen of the productive sectors, a representative consumer, labor and capital, foreign and public sectors and four accounts of direct and indirect taxes. All monetary values are measured in thousands of euros and all values of emissions in kilotons (kt) of CO_2.

The calibration process begins by assuming that the initial SAMAND00 represents the balance of Andalusia in 2000. From here, the model determines the value of the parameters to replicate this initial balance.

Specifically, the model calibrates the following parameters:

- All of the technical coefficients, parameters of participation and scale of the production function;
- All rates (except for the environmental tax in the first simulation and the environmental tax and social contribution rates in the second);
- The coefficients of the utility functions.

The environmental factors are obtained as a ratio of emissions and output for each domestic sector.

In this way, a balance is defined by equations with a vector of prices of goods and factors (p_j*, *w**, *r**), a vector of production outputs Y_j*, a level of gross capital formation, *INV**, a government deficit *SP** and foreign surplus *SE**, and a level of tax collection, so that the production plan maximizes the producer's profit, the plan for supply factors and demand of consumption and investment maximizes consumer utility, and all markets are cleared.

4. APPLICATION AND RESULTS

In this section, we present the results of our simulation of the introduction of an environmental tax to the economy of Andalusia, where we fix the value of ε at 10%. As mentioned in Section 3, the charge is modulated for each of the three energy goods responsible for emissions in proportion to emissions per unit of currency caused by coal, oil refining and gas. The percentage rates applied are 7.52 for coal, 1.31 for oil refining and 1.18 for gas.

In fact, we present two simulations. The first (SIM1) quantifies the pure effects of the introduction of a tax environment. In the second simulation (SIM2), we impose the condition that the public sector income does not change (revenue neutrality) by ensuring that the type of Social Security contributions levied on the hiring of labor services is set to the required amount. The first simulation estimates the impact of the introduction of an environmental tax on not only emissions but also prices, production, welfare, fundraising, etc. All variables change when the environmental tax is introduced. In the second simulation, the effects of the environmental tax are superimposed on those arising from a reduction of social contributions that changes the price of labor, although in the absence of unemployment, this policy cannot positively affect the level of occupancy.

4.1. Implementation of an environmental tax in the economy of Andalusia

The results presented are preliminary and should be treated with some caution. First, we examine the environmental effects of an environmental tax on prices, emissions and production, both domestic and total.

As shown in Table 1, the environmental tax raises the total price obtained by combining domestic prices and import prices, which record the total impact of the environmental tax. The increase is the result of the direct impact of the environmental tax on the price of energy goods and the indirect impact caused by rising domestic prices. This explains the increase in prices recorded for the three energy goods causing emissions, 7.82 for coal and 1.43 and 1.24 for refining and gas, which are higher than the rate of the environmental tax, 7.52, 1.31 and 1.18, respectively.

The environmental tax, as expected, also raises the prices of other goods and services, although the only significant increase is observed in electricity, the price of which increases 1.29 percent, although it is not directly taxed by the environmental tax.

Among the remaining non-energy sectors, the most notable increases were obtained in transportation, 0.19 percent; non energy extractives, 0.15 percent; Chemical, 0.14 percent; Construction and Water, 0.10 percent; and the Primary sector, 0.08 percent. Minor effects can be observed in the sectors of Commerce, Food, Other manufacturing, and Other services.

(TABLE 1. Percentage change in output and sectoral emissions)

The environmental tax does not greatly alter the price of capital[8] or consumer and investment price indices, which are weighted averages. The percentage changes for these two indices are much lower, 0.13 and 0.08 percent, respectively; than the simple

[8] Price variations are understood to be variations to the salary that remain unchanged, or the numeraire.

average that appears in the last row of Table 1. The aggregate price of energy has a great increase in coal (5.41 percent) and electricity (3.37 percent), and it increases by approximately 1.4 percent in most other sectors. It is only in the areas of oil refining and gas, which use large amounts of petroleum and natural gas (that is not subject to tax), that the increases are small.

In the next two columns, we present the variations in domestic production and total production for each sector. The biggest declines occurred in the energy sectors subject to the environmental tax, Coal, Gas Refining and Electricity.

Total production dropped slightly less than interior production, because the environmental tax raises the price of domestic non-energy goods and energy goods used for intermediate consumption in relation to imports. This induces the replacement of the domestic goods by imports, and this effect is likely to be more intense if the elasticity of substitution between domestic production and imports were more realistic than the values assumed in this model. The petroleum and natural gas sector, where there is no domestic production, also recorded a drop in imports of close to 1 percent, which can be explained by the decrease (1.06 percent) in refining production.

Among the non-energy sectors most affected by the environmental tax, the biggest stresses fall in domestic output in transport, non-energy extractive and chemical industries, which all make intensive use of energy goods. However, even for the worst case, the level of the decreases in domestic production is no more than 0.3 percent and that in total production is 0.26 percent. Less affected are the Water, Construction and Trade sectors, with cuts close to 0.1 percent. All other sectors show very small decreases in production. Reductions in total production are somewhat lower for the reasons already mentioned.

The third column shows that the change in sectoral emissions can be explained by the decrease in domestic output. Emissions are reduced in all sectors, and this is the main purpose of the tax. Average emissions decreased 3.12 percent, with the largest contributions to this reduction coming from coal producers (11.53 percent) and electricity (5.98 percent). Other sectors where emissions fell by more than 2 percent are Refining and Gas.

In other sectors, emissions decrease by between 1 and 2 percent. In assessing these results, it must be remembered that sectoral emission reduction depends on two factors: the relative intensity of the three energy pollutants goods and reducing the output is recorded. This explains why the decreases are larger for sectors as Commerce and Other manufactures that use more coal, than the Non-energy extractive, Chemical or Transport sectors. Despite a decrease in production is quite higher among these two last sectors.

Table 2 shows the values of key macroeconomic and fiscal variables before (Base) and after the simulation (SIM1) and the percentage change recorded. At the top of the table, we present the absolute values of real disposable income, real GDP and the revenue figures in millions of Euros. The ratios in the lower panels indicate the variation of the main aggregates and emissions relative to GDP.

In this walrasian model, in which capital and labor markets are clearance, the income of both factors remain almost constant, due to price of capital is held constant. The decrease in real disposable income of the representative consumer is, therefore, explained by the increase in prices of consumer goods purchased by households and the price savings or price of the investment. A similar result is obtained when calculating the equivalent or compensatory changes resulting from tax reform.

The change in real GDP was obtained by valuing the components of expenditure at base year prices, resulting in a decrease rather than the real disposable income, because public expenditure and exports remain unchanged.

Table 2 also includes the increase in regional government revenues, disaggregated into direct and indirect tax revenues. Indirect tax revenues are likewise disaggregated into social contributions, taxes on products and imports, and the environmental tax.

We do not see a significant increase in direct tax revenues because of the drop in disposable income that accompanies the environmental tax. In contrast, indirect tax revenues increase by 0.51 percent after the new environmental tax is levied, despite the fact that the price increase accompanying the new tax does not fully offset the decrease in production.

(TABLE 2. Main aggregates and fiscal variables)

There are slight changes in the composition of GDP after implementation of the environmental tax. Consumption and investment decrease by .083 percent and .119 percent, respectively; public purchases and exports, constant in real terms by definition, decrease by .071 and .027 percent, respectively, due to the effect of prices; and imports decrease by .251 percent because of reduced activity, especially the reduction of petroleum imports. Finally, the government deficit is reduced by almost 1.4 percent due to increasing revenues from the introduction of environmental tax.

The last line of Table 2 indicates kilotons of CO_2 emissions per unit of real GDP. The introduction of the environmental tax reduces the amount from 0.86 to 0.83, a decline of 2.61 percent, indicating the effectiveness of the tax in reducing emissions. In short, the implementation of the environmental tax carries a dividend in terms of environmental pollutant emissions reduction, but it also causes a general decline in production in the productive sectors and a decline in real GDP. Will these findings hold when the revenue provided by the environmental tax is put back into the private sector through a reduction in social contribution rates?

4.2. Implementation of an environmental tax with revenue neutrality in the Andalusian Economy.

This section presents the results of a simulation that consist in the introduction of an environmental tax in a revenue-neutral scenario. Specifically, in this scenario, the additional revenue provided by the environmental tax is used to reduce the social contribution rates of employers so that tax revenues will remain the same. The objective of this simulation is to detect whether the Andalusian economy can obtain the so-called double dividend after implementing the environmental tax.

The notion of a double dividend, introduced by Pearce (1991), alludes to the possibility that, in addition to a first dividend of consistent improvements in the environmental policy objective, the introduction of an environmental tax could also generate an economic second dividend. This second interim dividend, generated by the recycling of revenue from environmental taxes back into the private sector, can take various forms: an improvement in employment levels (double dividend of employment); an improvement in the efficiency of the tax system, obtained by altering the composition of taxes and using environmental tax revenues to finance a reduction in rates in any distortionary tax, resulting in a zero-sum[9] transfer (weak double dividend); or an increase in economic welfare through a consistent increase in real disposable income (strong double dividend[10]). The presence of a double dividend is an empirical question to be resolved in each case through a simulation of tax policies.

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[9] Goulder (1995).

[10] Goulder (1995) and Mooij (1999).

In Spain, some studies have been published that seek to establish whether a double dividend can be obtained from tax policies. Manresa and Sancho (2005) simulate the introduction of an environmental tax in a model dominated by fixed coefficients in production and that imposes restrictions on the prices to endogenise unemployment. In this context, they estimate the impact of introducing a tax on the use of energy goods, including a scenario under which new tax revenues are used to reduce the social contribution rates. These authors conclude that under the latter scenario, it is even possible to get what they call a "triple dividend," i.e., a reduction in emissions, an increase in employment and improved efficiency in the tax system. This triple dividend can be quantified as an increase in the welfare of the representative family, estimated by the equivalent variation. Likewise, André *et alia* (2005) study an environmental tax implementation in Andalusia and similarly conclude that it is possible to obtain a double dividend when new tax revenues are recycled to reduce Social Security contributions; but this result is not retained when the revenues are used to lower the tax rate levied on income.

Below are the results obtained in our estimation of a scenario under which the environmental tax is implemented in such a manner that its revenue is used to rescale the rates of social contributions paid by employers. This model differs from previous work in two important respects. First, we aggregate energy products, making this factor interchangeable with labor and capital. Second, in our model, there is no friction in the labor market, and therefore, the labor market is empty, thereby excluding the possibility of a second dividend of employment.

In Table 3, we can see the effects of the model on prices, domestic and total production, and sectoral emissions. The variation in prices now registers both the positive effect of the environmental tax on prices and the negative effect of the reduction in contribution rates. The biggest price increases occur, as in the previous simulation, in the energy sectors on which the environmental tax is directly levied, coal, gas and refining, as well as the electricity sector, which uses these products as intermediate goods[11]. Three other energy-intensive sectors are Non-energy extractive, Chemical and Transport. In these sectors, the effect of the environmental tax is mitigated but not completely offset by the reduction in contribution rates.

(TABLE 3. Percentage change in output and sectoral emissions)

In other sectors, prices fell slightly, a little more in those sectors where labor costs are greater, such as Other services, Commerce and Construction. As in the first simulation, the environmental tax barely affects the price of capital. CPI rises slightly less (0.015 percent), and the price index of investment registers a decrease (0.032 percent). In addition, the price of value added falls rather than in SIM1 (0.183 versus 0.006 percent), reflecting lower labor costs, whereas the aggregate price of energy rises slightly less in SIM2 (0.963 percent) than in SIM1 (0.999 percent).

In terms of domestic production, decreases are seen in energy sectors and in some energy intensive sectors (i.e. non-energy extractive), as well as other sectors, such as Construction, which moved a substantial part of its production to investment. In other areas, such as Transport and Other manufactures, there are no significant changes. Apart from the price effects, we must remember that, in this model, aggregate investment is determined by representative household savings, the budget surplus and the surplus of the foreign sector, so that when the environmental tax is recycled, disappear the surplus

[11] These findings may differ in a model with unemployment and underutilized capacity of capital. In such a model, the environmental tax would impose a drain on capital and labor markets, without any capital available to substitute for the factors whose prices have increased due to their high energy requirements with factors whose relative price has fallen.

observed in SIM1, and the output drop may be intensified in areas such as construction because the importance of investment for its production. These effects are maintained when comparing variations in total production. In SIM2, the reduction in total production is only slightly higher than that for petroleum imports.

The last column of Table 3 shows the sectoral emissions. By recycling the revenues generated by the environmental tax, sectoral emissions decreased in all sectors, resulting in significant decreases in those sectors in which production decreased. Emissions are also reduced in those sectors where the decreased production is smaller than in the SIM1, a result we attribute to lower use of polluting energy due to a more intensive use of aggregated labor-capital.

In Table 4, we compare the results for the main aggregates and macroeconomic variables in the base year and after tax reform.

First, when the environmental tax revenues are recycled, the real disposable income of households declines less than in the previous simulation, increasing both consumption and private savings. However, real GDP falls by almost the same amount, demonstrating that the increase in consumption is offset by a reduction in investment, eliminating the improvement in budget surplus seen in SIM1.

(TABLE 4. Main aggregates and fiscal variables)

Regarding the change in disaggregated tax revenues, a negligible reduction in the amount of direct environmental tax revenues and a drop in the quantity of energy used cancelled the effect of increases in energy prices. Because of this, we see a slightly larger decrease in tax revenues from production in SIM1 (0.33 versus 0.19 percent), a significant fall in prices (0.83 percent) in SIM2 and also a reduction of direct tax revenues in SIM2. The lower tax revenues on the production and direct tax take a part of the tax revenue gained from the environment and due to this fact, social contributions can not be reduced more.

Regarding the composition of GDP, the only noteworthy change from Sim1 to Sim2 is the reduction of the surplus in the foreign sector, caused by the reduction of petroleum imports and, as mentioned earlier, a reduction in the aggregate investment in the economy. The reduction of emissions per unit of real GDP remains the same between the two simulations.

In short, we may conclude that although the recycling of environmental tax revenues can reduce contribution rates and increase the real disposable income of the representative family, real GDP does not improve with respect to the first simulation. The positive impact of increased consumption and savings by the representative family is counterbalanced by the contraction of the surplus and public sector foreign investment, reducing the aggregate. Ultimately, recycling the environmental tax revenues reduces the contraction in real disposable income caused by the introduction of environmental tax, but does not prevent a reduction in real GDP in the economy.

5. CONCLUSIONS

This paper introduces an environmental tax that raises the price of energy goods that cause CO_2 emissions in order to reduce those emissions. The effects of green tax reform on the Andalusian economy have been assessed with a walrasian type of general equilibrium model that, unlike linear models, reflects the production structure with more flexibility and models the behavior of producers, the representative consumer, the government and the foreign sector. In addition, markets clearance takes into account the limitations of available factors.

The model quantifies the impact of reform on prices, production and sectoral emissions and estimates the impact on key macroeconomic variables and tax receipts. We have considered two alternative scenarios: the first estimated the pure effects of an environmental tax, and the second estimated the effects of an environmental tax when the revenue from that tax is used to reduce the effective rates of social contributions. The purpose of comparing the two scenarios is to know whether, in addition to the environmental dividend, the recycling of tax revenue gained from the environmental tax can provide an economic dividend by increasing the real income of the family or real GDP.

The introduction of environmental tax increases appreciably the prices of commodities that cause emissions, such as coal, gas and refining, and the prices of other goods and services that use such energy goods through intermediate consumption. These price effects are attenuated in some labor-intensive sectors by recycling environmental tax revenues and reducing contribution rates. In both simulations, environmental dividends are very similar, i.e., there is a significant reduction in sectoral emissions and in total emissions, at just over 3 percent. The energy efficiency indicators (emissions per unit of real GDP) also recorded a decrease of 2.7 percent. However, these results did not allow us to conclude that there is no environmental dividend, because although real disposable income does not decrease as much when environmental tax revenues are recycled, the decrease in real GDP is maintained in the second stage. As indicated above, the hypothesis that factor markets are cleared makes it impossible to reduce Social Security contributions and raises the employment, income and activity levels.

It should be mentioned that the energy sectors are most affected, highlighting the impact of the environmental tax on coal production, refining, gas and electricity, and oil imports. In general, the impact on non-energy sectors is small and only reaches values that are noteworthy in the case of the Non-energy extractive industries, Transport and Chemistry. Construction also recorded a significant decrease in production when the environmental tax revenue is recycled and the collection from the government remains unchanged.

The results obtained with this model should be read with caution. One of the primary objectives of the authors is to extend this research in several directions. First, it would be desirable to compare these results with those obtained by incorporating unemployment, as described by Manresa and Sancho (2005) and Andre et al. (2005), or underused capacity. Second, it would be desirable to estimate the model while separating secondary and primary energy, as Rodriguez (2003) does in his work, and to examine the sensitivity of the results when using other nests. Finally, although the Cobb-Douglas technology allow substitution between factors, it would be desirable to use other, more flexible production functions.

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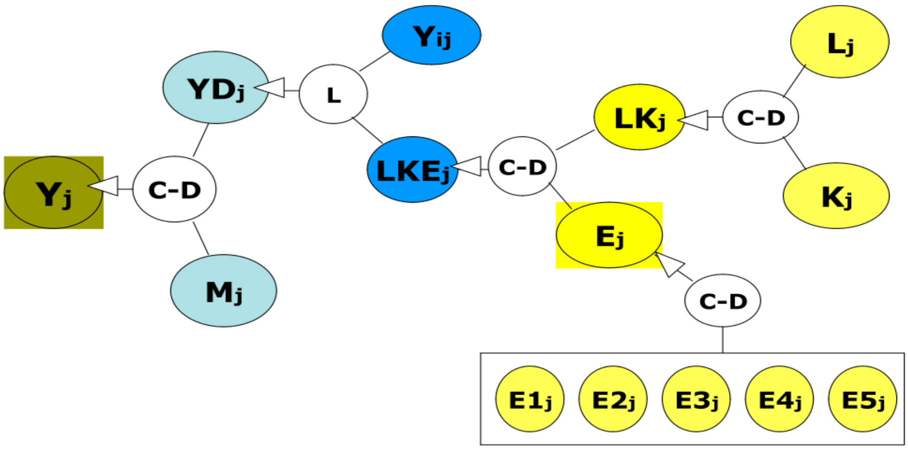
APPENDIX: TABLES AND FIGURES

FIGURE 1. The nested function of production.



Source: Own elaboration.

TABLE 1. Percentage change in output and sectoral emissions.

SECTORS		Prices	Domestic production	Total production	Direct emissions
1	Primary	809	-55	-38	-1.374
2	Coal	78161	-5648	-5564	-11.528
3	Petroleum and natural gas	0	0	-933	0.000
4	Non-energy extractive	1528	-218	-108	-1.143
5	Refining	14285	-1060	-1053	-2.331
6	Electricity	12943	-1395	-1219	-5.983
7	Manufactured gas	12437	-1028	-1027	-2.246
8	Water	1026	-104	-99	-1.363
9	Food	578	-50	-34	-1.375
10	Other manufactures	435	-100	-65	-1.624
11	Chemical	1384	-217	-93	-1.105
12	Construction	1042	-95	-90	-1.577
13	Commerce	695	-93	-93	-1.962
14	Transport and communication	1881	-290	-257	-1.393
15	Other services	298	-36	-35	-1.428
Simple average		9080	-156	-160	-3115

Source: Own elaboration.

TABLE 2. Main aggregates and fiscal variables.

	BASE (Mill. €)	SIM1 (Mill. €)	Percentage change
Real disposable income	80019.44	79944.17	-0.094
Real GDP	86215.97	86185.35	-0.036
Total Revenue	26805.07	26905.22	0.374
Raising direct taxes	7709.41	7711.40	0.026
Raising indirect taxes	19095.66	19193.82	0.514
Net taxes on production and imports	9624.01	9605.54	-0.192
Payroll taxes	9471.65	9471.59	-0.001
Environmental tax	0.0	116.69	---
	BASE (%)	SIM1 (%)	Percentage change
Consumption/GDP	71.17	71.12	-0.083
Investment/GDP	26.14	26.11	-0.119
Public expenditure /PIB	22.21	22.20	-0.071
Exports/GDP	25.35	25.34	-0.027
Imports/GDP	44.87	44.76	-0.251
External deficit/GDP	11.67	11.56	-0.922
Revenue /GDP	31.09	31.17	0.265
Public deficit /GDP	7.17	7.07	-1.317
	BASE (Kt CO_2 by Mill. €)	SIM1 (Kt CO_2 by Mill. €)	Percentage change
Total emissions/GDP	0.857	0.833	-2.610

Source: Own elaboration.

TABLE 3. Percentage change in output and sectoral emissions.

SECTORS		Prices	Domestic production	Total production	Direct emissions
1	Primary	-35	-9	-17	-1.448
2	Coal	7709	-5651	-5597	-11.589
3	Petroleum and natural gas	0	0	-1032	0.000
4	Non-energy extractive	87	-285	-222	-1.307
5	Refining	1392	-1138	-1133	-2.390
6	Electricity	1187	-1411	-1250	-6.032
7	Manufactured gas	1202	-1115	-1114	-2.327
8	Water	-48	-62	-65	-1.455
9	Food	-45	-4	-16	-1.456
10	Other manufactures	-21	-110	-127	-1.758
11	Chemical	80	-175	-103	-1.146
12	Construction	-20	-314	-315	-1.924
13	Commerce	-80	-61	-61	-2.058
14	Transport and communication	74	-283	-270	-1.496
15	Other services	-127	-28	-33	-1.558
Simple average		9080	0.811	-0.178	-200

Source: Own elaboration.

TABLE 4. Main aggregates and fiscal variables.

	BASE (Mill. €)	SIM2 (Mill. €)	Percentage change
Real disposable income	80019.49	79963.44	-0.070
Real GDP	86215.97	86180.47	-0.041
Total Revenue	26805.07	26805.07	0.000
Raising direct taxes	7709.41	7704.27	-0.067
Raising indirect taxes	19095.66	19100.80	0.027
Net taxes on production and imports	9624.01	9591.45	-0.338
Payroll taxes	9471.65	9392.83	-0.832
Environmental tax	0.0	116.52	---
	BASE (%)	SIM2 (%)	Percentage change
Consumption/GDP	71.17	71.17	-0.001
Investment/GDP	26.14	26.14	-0.355
Public expenditure/PIB	22.21	22.21	-0.047
Exports/GDP	25.35	25.35	0.061
Imports/GDP	44.87	44.87	-0.197
External deficit/GDP	11.67	11.56	-0.947
Revenue/GDP	31.09	31.11	0.065
Public deficit/GDP	7.17	7.15	-0.250
	BASE (Kt CO_2 by Mill. €)	SIM2 (Kt CO_2 by Mill. €)	Percentage change
Total emissions/GDP	0.857	0.834	-2.679

Source: Own elaboration.

TABLE 5

Emissions Vector C (Kt CO_2/ 1000€)

	Coil	Oil and Natural Gas	Oil Refining	Electricity	Manufactured Gas
Intermediate Demand	46.40	0.00	8.08	0.00	7.25
Final Demand	27.98	0.00	4.65	0.00	3.26

Source: Own elaboration starting from Manresa & Sancho (2004).