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PERFORMING AN ENVIRONMENTAL TAX REFORM IN A REGIONAL ECONOMY. A COMPUTABLE GENERAL EQUILIBRIUM APPROACH

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A Computable General Equilibrium Approach

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ABSTRACT

We use a Computable General Equilibrium model to simulate the effects of an Environmental Tax Reform in a regional economy (Andalusia, Spain). The reform involves imposing a tax on CO_2 or SO_2 emissions and reducing either the Income Tax or the payroll tax of employers to Social Security, and eventually keeping public deficit unchanged. This approach enables us to test the so-called double dividend hypothesis, which states that this kind of reform is likely to improve both environmental and non-environmental welfare. In the economy under analysis, an employment double dividend arises when the payroll tax is reduced and, if CO_2 emissions are selected as environmental target, a (limited) strong double could also be obtained. No double dividend appears when Income Tax is reduced to compensate the environmental tax.

Keywords: environmental tax reform, computable general equilibrium, double dividend.

JEL Classification: D58, H21, H23.

Running title*:* ETR in a Regional Economy. CGE approach

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1. INTRODUCTION

Some economists have argued that an environmental tax reform (ETR henceforth) consisting of taxing polluting emissions and recycling the so-obtained revenue by reducing other distorting taxes, in such a way that public revenue remains unchanged, can give rise to the so-called *double dividend*, that is, an environmental improvement (*green dividend*) and a reduction of fiscal distortions (*blue dividend*) so that non-environmental welfare would also increase.

The relevance of a double dividend has to do with the practical implementability of an ETR. Any environmental policy is likely to have some economic costs by worsening the performance of some economic variables, such as production, employment, inflation, and ultimately (non-environmental) welfare. To make a decision, a benefit-cost analysis is needed, in order to compare the environmental benefits and the economic costs from such a policy. The most difficult part of this analysis is how to measure environmental benefits, which do not usually have a market value. Nevertheless, if a double dividend exists, it is possible to improve the environmental quality without any cost in terms of non-environmental economic welfare. In this case, it can be argued that the fiscal reform is desirable even without an explicit valuation of the environmental benefits. Note that the environmental policy could be justified by itself, even it has some economic cost; in this sense, the fact that a double dividend exists is a sufficient, but not a necessary condition, to justify an ETR.

According to Mooij (1999), there is a consensus among all the authors concerning the definition of the green dividend, but there exist different versions of the blue dividend. The so-called *weak double dividend* version states that the social welfare is higher when an environmental tax is compensated by reducing a distorting tax rather than by a lump-sum transfer. A *strong double dividend* exists if, apart from the environmental improvement, the non-environmental welfare is greater after performing the reform than before. Finally, an *employment double dividend* happens if the employment level increases after the reform, as compared with the situation before the reform.

Basically all economists agree that there exists a green dividend, and most of them also agree that a *double weak dividend* is also likely to exist, but there is a controversial debate about the strong double dividend and the employment double dividend. The theoretical literature has not obtained clear-cut conclusions so far, but it suggests that the possibility to obtain a double dividend is low and it is subject to very stringent conditions about tax recycling. Pearce (1991), Repetto et.al. (1992), Nordhaus (1993) or Grubb (1993) among others argue that it is possible to improve tax efficiency by means of an ETR, while others, as Bovenberg and Mooij (1994) argue that this is not possible, in general, because environmental taxes are likely to increase, rather than reduce, previous distortions.

Parry (1995) points out the relevance of choosing a partial equilibrium or a general equilibrium approach to answer this question. Partial equilibrium models do not take into account the interactions between environmental taxes and previous distortions, and these effects tend to cause the double dividend to hold in partial equilibrium models but not in general equilibrium models. This is because the environmental tax eventually falls on labor income, so that labor taxes and emission taxes distort the labor market in a similar way. However labor taxes are more efficient from the levying point of view because environmental taxes also distort the relative prices between polluting and non-polluting goods, which erodes the tax base. So, from a non-environmental point of view, emission taxes are likely to cause a larger excess of burden.

Notwithstanding, the economic literature also describes some mechanisms that may cause a strong double dividend, or an employment double dividend to happen in a general equilibrium framework. An ETR could facilitate wage moderation and the reduction of labor market distortions in a situation in which imperfect competition has led to excessively high wages (Brunello, 1996; Carraro et.al., 1996). Bovenberg (1994) and Carraro and Soubeyran (1996) show that, if the initial tax system is suboptimal from a non-environmental point of view, an ETR can simultaneously reduce pollution and unemployment. We can conclude that opportunities to get a double dividend typically arise when there exist some market failures or some imperfections in the tax system (see also Bovenberg and Goulder, 2002). For a survey on ETR and the double dividend, see Mooij (1999) or Goulder (1995).

Given the difficulties to obtain clear-cut theoretical conclusions, it makes sense to perform an empirical analysis to test the economic effects of a specific reform in a selected country or region, by means of a suitable applied model. A number of authors, like Bovenberg and Goulder (1996), Bye (2000), Dessus and Bussolo (1998), Wender (2001), Xie and Saltzman (2000) o Yang (2001), have used Computable General Equilibrium (CGE henceforth) models to assess the economic effects of an ETR. These models perform a disaggregate representation of all the activity sectors and the equilibrium of all markets, according to basic microeconomic principles.

In Spain, Manresa and Sancho (2002), Gomez-Plana et.al. (2003) and Labandeira et.al. (2003) use CGE models to simulate the effect of environmental tax reforms nationwide. We are not aware of any application in the regional level. In this paper a CGE model is used to evaluate the environmental and economic effects of an ETR in a regional economy, in this case, Andalusia (Spain). Specifically, four simulations are made, by combining the introduction of a tax on CO_2 or SO_2 emissions with a reduction in Income Tax (IT hereafter) or in the payroll tax of the employers to Social Security (PT hereafter). We use an extension of the model by Cardenete and Sancho (2003), including polluting emissions and emission taxes.

The results show that an employment double dividend is likely to arise when the PT is reduced to compensate the environmental tax. In the case of the CO_2 tax, a strong double dividend is also obtained for low values of the environmental tax. No (employment or strong) double dividend exists when the environmental tax revenue is recycled by reducing the IT.

The rest of the paper is organized as follows. Section 2 displays the most important features of the CGE model[1] and the databases. Section 3 presents and justifies the simulations performed, and specifically, the pollutants to be taxed and the selected tax combinations. Section 4 summarizes the results and offers some economic interpretations. Section 5 provides some concluding remarks.

2. THE MODEL AND THE DATABASES

2.1. The model

The model comprises 24 productive sectors, after aggregation of the 1990 Input-Output tables of Andalusia. The production technology is given by a *nested production function*. The domestic output of sector *j*, measured in euros and denoted by Xd_j, is obtained by combining, through a Leontief technology, outputs (including energy) from the rest of sectors and the value added VA_j. In turn, this value added is from primary inputs (labor, *L*, and capital, *K*), combined by a Cobb-Douglas technology. Overall output of sector *j*, Q_j, is obtained from a Cobb-Douglas combination of domestic output and imports $Xrow_j$, according to the Armington hypothesis (1969), in which domestic and imported products are taken as imperfect substitutes.

The government raises taxes to obtain public revenue[2], as well as it gives transfers to the private sector, *TPS*, and demands goods and services, GD_j. PD gives the final balance (surplus or deficit) of the public budget[3]:

$$PD = R - TPS\ cpi - GD_j\ p_j \tag{1}$$

cpi being the Consumer Price Index and p_j a production price index before Value Added Tax (VAT hereafter) referring to all goods produced by sector *j*. Tax revenue includes that raised from the environmental tax.

Let E_j denote polluting emissions from sector *j*, measured in CO_2 or SO_2 tons. Then, we have the following equation, which assumes a linear relationship between production and emissions:

$$E_j = \alpha_j\ Q_j \tag{2}$$

where α_j measures the amount of pollution for every euro of output produced in sector *j*. The technical parameter α_j accounts for the differences in pollution intensities across sectors. Typically, very energy-intensive sectors (and, especially fossil-fuels-intensive) are also very polluting (and hence display a high value of α_j)[4].

The government imposes a tax of *t* euros per ton of emissions. As a consequence, each sector *j* pays

$$T_j = t\ E_j \tag{3}$$

Note that the different pollution intensity across sectors causes that the same tax on pollution implies a different economic burden with respect to output. Substituting (2) into (3), the amount to be paid by sector *j* can be written as

$$T_j = \beta_j\ Q_j \tag{4}$$

where $\beta_j = t\ \alpha_j$ is the marginal and average tax rate of sector *j* in terms of euro paid per euro produced (see equation A.8 in the appendix for the exact specification of the environmental tax in the CGE model).

There is only one foreign sector, which comprises the rest of Spain, Europe and the rest of the world. The balance of this sector is given by

$$ROWD = \sum_{j=1}^{24} rowp\ IMP_j - TROW - \sum_{j=1}^{24} rowp\ EXP_j \qquad (5)$$

where IMP_j denotes imports of sector *j*, EXP_j exports of sector *j* and *TROW* transfers from abroad for the consumer. *ROWD* is the balance of the external sector.

Final demand comes from investment, exports and consumption demand from households. In our model, there exist 24 different goods –corresponding to productive sectors- and a representative consumer who demands present consumption goods and saves the remainder of her disposable income. Consumer income (YD henceforth) equals labor and capital income, plus transfers, minus direct taxes:

$$YD = w\ L + r\ K + cpi\ TPS + TROW - DT\ (r\ K + cpi\ TPS + TROW)$$

$$- DT\ (w\ L - WC\ w\ L) - WC\ w\ L \qquad (6)$$

where *w* and *r* denote input (labor and capital) prices and *L* and *K* input quantities sold by the consumer, *DT* is the IT rate and *WC* the tax rate corresponding to the payment of the employees to Social Security (ESS hereafter). The consumer's objective is to maximize her welfare, subject to her budget constraint. Welfare is obtained from consumption goods CD_j (j = 1,…, 24) and savings *SD*, -according to a Cobb-Douglas utility function:

$$\begin{aligned} &\text{maximize} \quad U\ (CD_1,\ldots,CD_{24}, SD\ ) = \left(\prod_{j=1}^{24} CD_j^{\alpha_j} \right) SD^{\beta} \\ &\text{s.t.} \quad \sum_{j=1}^{24} p_j CD_j + p_{inv}\ SD\ = YD \end{aligned} \qquad (7)$$

p_{inv} being an investment price index.

Regarding investment and saving, this is a *saving driven* model. The closure rule is defined in such a way that investment is exogenous, savings are determined from the consumer's decision and both variables are related with the public and foreign sectors by the following identity:

$$\sum_{j=1}^{24} INV_j\, p_{inv} = SDpinv + PD + ROWD \qquad (8)$$

Labor and capital demands are computed under the assumption that firms minimize the cost of producing value added. In the capital market we consider that supply is perfectly inelastic. In the labor market, there is a feedback between the real wage rate and the unemployment rate. This feedback somehow represents rigidities in the labor market that are related to the power of unions or other friction inducing factors (see Kehoe et al. (1995)). Specifically, we consider that the real wage satisfies the following feedback condition:

$$\frac{w}{cpi} = \left(\frac{1-u}{1-\bar{u}}\right)^{\frac{1}{\theta}} \qquad (9)$$

where u and $\bar{u}$ are the unemployment rates in the simulation and in the benchmark equilibrium respectively, and θ is an elasticity constant that represents the degree of flexibility of the real wage (as is usual in similar studies, we set θ equal to 1). This formulation is consistent with an institutional setting where the workers decide real wage taking into account the unemployment rate -according to equation (9)- and employers decide the amount of labor.

The activity levels of public and foreign sectors are fixed, while the relative prices and the activity levels of the productive sectors are endogenous variables.

The equilibrium of the economy is given by a price vector for all goods and inputs, a vector of activity levels, and a value for public income such that the consumer is maximizing her utility, the productive sectors are maximizing its profits (net of taxes), public income equals the payments of all economic agents, and supply equals demand in all markets.

This CGE model follows the basic principles of the walrasian equilibrium -as in Scarf and Shoven (1984), Ballard et al. (1985) or Shoven and Whalley (1992)-, enlarged by including both public and foreign sectors and explicitly accounting for polluting emissions.

2.2. Databases and calibration

The main data used in this paper come from the 1990 social accounting matrix for Andalusia (SAM hereafter, see Cardenete, 1998). Emission data are obtained from the 1990 environmental Input-Output tables for Andalusia (TIOMA90), carried out by the regional environmental agency[5], which show real observed data on different air pollutants released from 74 activity sectors, which were aggregated into 24 to match the SAM structure. There is a more recent SAM for Andalusia, specifically, from 1995. Unfortunately, as there are no, disaggregate enough, official pollution data by sectors, for any year after 1990, we have decided to use the 1990 SAM for the sake of consistency.

The numerical values for the economic parameters are obtained by the usual procedure of calibration (see, for example, Mansur and Whalley, 1984). Specifically, the following parameters are calibrated: all the technical coefficients of the production functions, all the tax rates (except for the environmental tax) and the coefficients of the utility function. The environmental coefficients α_j are obtained from equation (2), i.e., dividing the observed amount of pollution by the amount of output for every sector. The calibration criterion is that of reproducing the 1990 SAM as an initial equilibrium for the economy, which is used as a benchmark for all the simulations. In such an equilibrium, all the prices and the activity levels are set equal to one, so that, after the simulation, it is possible to observe directly the change rate of relative prices and activity levels. The amount of pollution for sector *j* is simulated by multiplying the output of that sector by the calibrated value of parameter α_j.

The SAM comprises 24 industry sectors, two inputs (labor and capital), a saving/investment account, a government account, direct taxes (IT and ESS) and indirect taxes (PT, VAT, output tax and tariffs), a foreign sector and a representative consumer.

3. SIMULATIONS PERFORMED

In the simulations performed in this paper, we assume that a tax is imposed on the CO_2 or SO_2 emissions. The revenue obtained from such a tax is recycled by reducing PT or IT, so that, four different policy combinations are simulated.

It is well known that Carbon and Sulfur Oxides are among the main polluting substances released to the atmosphere. In Andalusia, more than one million tons of SO_2 and CO_2 are released every year (Consejería de Medio Ambiente[6], 2001), being industry and road transport the most polluting sectors.

We have chosen CO_2 because of its well known severe impacts on the ozone layer, global warming, and climate change, which have forced some governments to impose taxes on CO_2 emissions in order to cut them down (Bosquet, 2000). Given the global effects of this pollutant, a tax on CO_2 emissions is more likely to be set in the national rather than regional level, so the results concerning this pollutant can be interpreted as the likely regional effects of a hypothetical national tax reform. Regarding SO_2, it is one of the main air pollutants in Andalusia and its local effects make it a suitable aim for a regional environmental policy.

Chemical and energy industries are the main responsible for the emissions, accounting for about 77 % of the overall SO_2 emissions in 1990[7] (Sociedad para el Desarrollo Energético de Andalucía, 1994-2000).

Regarding the taxes to be reduced for recycling revenue, we have selected the payroll tax (PT) and income tax (IT). PT is perhaps the one which has been analyzed more deeply in the literature (Bosquet, 2000), perhaps partly because of the concern about unemployment in Europe (see, for example, Blanchard and Katz, 1997). The unemployment problem is especially severe in Spain (see, for example, Blanchard et.al., 1995) and even more in Andalusia[8]. As we have discussed in the introduction, opportunities to get a double dividend typically arise when there exist some market failures or some imperfections in the tax system. The high unemployment rate in Andalusia can be interpreted as a sign that some market and/or fiscal imperfections exist, suggesting that there could be some room to improve the tax system and get some efficiency gains. Regarding PT, we should remark that, according to the Spanish law, this tax could be modified only by the central Spanish government, and not by a regional government. Therefore, as this paper focuses on the economic effects of an ETR in a regional economy, the results involving this tax can be interpreted, first, as measuring the regional effects of a hypothetic reform performed from the central government or, second, as measuring the potential gains for the regional economy if the local government received power to modify this tax in the future.

As for the IT, we have found very few empirical related references as for this tax, despite the recommendations of the European Commission (Durán, 2001). Nevertheless, this tax is included in the analysis, first, because of its great relevance in the Spanish Tax System, and second, because regional governments have a (limited) ability to manage this tax, so that a reform involving IT can be performed more easily in a regional economy than one involving PT.

Combining both pollutants and both taxes, we obtain four possible ETR's. Among the four, the SO_2/IT combination is the most plausible from a regional point of view, while the CO_2/PT combination is the most plausible from a national point of view. The other two intermediate cases are also simulated for the sake of completeness. The (regional) economic effects of each one are simulated, focusing specially on Gross Domestic Product (GDP) and Disposable Income (YD) in real terms, Equivalent Variation (EV) as a measure of consumer (non-environmental) welfare, unemployment and inflation. This information allows us to discuss the existence of a (strong or employment) double dividend for the economy under study.

As noted by Bovenberg and de Mooij (1994), an environmental tax is likely to introduce further economic (non-environmental) distortions. When another distorting tax is reduced as compensation, there are two opposite effects, which yield an ambiguous result, depending on how distorting the tax to be reduced is. If we reduce a very strongly (slightly) distorting tax, it might provide a welfare improvement that could (could not) compensate the distortion introduced by the environmental tax, in order to give a final positive (negative) impact on non-environmental welfare. This reasoning could also work the other way round: if we observe that an ETR provides a positive (negative) overall effect on welfare, we can conclude that the tax that has been reduced is more (less) distorting than the environmental tax.

As the magnitude of both types of emissions is very different[9], the value of the tax rates has to be set in sensible levels regarding the fiscal pressure they impose on the firms. Instead of performing the simulation for a single value of the environmental tax rate (as in other related articles), in order to obtain more accurate quantitative information concerning the sensitivity of different economic variables, we perform the simulation for a parametric range, with a minimum of α=0,5 and a maximum of 3 euros per unit of pollutant (tons for SO_2 and thousand tons for CO_2). These values imply an average tax rate on sales (β, see equation (4) above) that roughly ranges from 0,7% to 4% in the SO_2 reform and from 0,17% to 1.06% in the CO2 reform. In every simulation, once the environmental tax rate is exogenously fixed, the compensating tax (PT or IT) is decreased with the criterion of keeping real public deficit unchanged. There is no minimum exempt, so that, firms have to pay from the first polluting unit.[10]

4. RESULTS

Given the different magnitude of both substances, it is not suitable to perform a precise quantitative comparison between the results concerning both pollutants. So, every reform is simulated separately, quantitative comparisons can be made for reforms on the same pollutant, and just some general qualitative comparisons can be made across different pollutants.

First, we focus on the reforms involving a tax on CO_2 emissions. Table 1 displays the main results, including the change rate (%) of emissions, real GDP, real YD, unemployment and Consumer Price Index (CPI hereafter) with respect to the benchmark situation, as well as EV with respect to the benchmark situation.

When the **CO_2** tax is compensated with **PT,** emissions monotonically decrease with the tax rate, as expected. Nominal Output and Income decrease, but as prices also decrease, both GDP and YD increase in real terms. Nevertheless, while real GDP monotonically increases with the tax rate, YD reaches a maximum (0,03 % increment with respect to the benchmark value) when the environmental tax rate equals 1.5 euros per thousand tons, and decreases from that point on (although, it keeps above the benchmark level).

As a consequence of lower labor costs, unemployment rate monotonically decreases, reaching a reduction larger than 3%, so that an employment double dividend arises. Non-environmental welfare, as measured by EV, also increases monotonically for tax rates smaller or equal than 2.5, and it reaches a maximum at this point and decreases for larger values. This event fulfills the definition of strong double dividend. In fact, this simulation is the only one that shows a (limited) strong double dividend result. These results follow the evidence obtained by several economists, concerning the strongly distorting effects of labor taxes, and more specifically, the payroll tax in the Spanish Tax System[11]. The reduction in this tax overpowers the distorting effects of the environmental tax.

INSERT TABLE 1

When the CO_2 tax is compensated by reducing Income Tax, no (strong or employment) double dividend follows. Emissions reduce, as expected, but all economic variables monotonically worsen: real GDP and YD decrease, CPI increases (with an inflation rate up to 1,5 %), as well as unemployment rate (with an increment up to 4,25%). In this case, we can conclude that the distorting effects of the environmental tax (which depress consumption and economic activity) overpower the incentive effect from reducing IT.

By comparing the economic effects of both reforms (figure 1), we can see that the most sensitive variable is unemployment, showing the highest change rate in absolute value (positive in the first reform, and specially negative in the second) among all the variables under study.

Note also that the emission reduction is larger in the IT reform (up to 2%) than in the PT reform (hardly 1%). To understand this difference, we can rationalize the final effect of the ETR on emissions, as being the result of combining two separate mechanisms that can be called *scale effect* and *substitution effect*. Regarding the former, given that pollution is a consequence of economic activity, any policy that fosters or depresses economic activity tends to increase or decrease polluting emissions as a side effect. On the other hand, the environmental tax incentivates the activity of cleaner sectors and disincentivates that of dirtier ones, in such a way that, apart from changing the scale of the economic activities, their composition is altered as well (substitution effect). The latter effect is likely to be always negative (that is, to reduce emissions), while the sign of the scale effects is ambiguous because it depends on the impact on economic activity. In the IT reform, the decrease in the activity level induces further emission reductions, so both scale and substitution effects are negative, while the PT reform fosters economic activity and causes an indirect increasing effect on emissions (positive scale effect) which absorbs part of the (negative) substitution effect.

We can conclude that the IT reform is more successful concerning environmental effects, but imposes higher economic costs, while the income tax reform has slighter environmental effects, but does not appear to have any cost in terms of non-environmental welfare.

INSERT FIGURE 1

No strong double dividend arises when reducing PT compensates a SO2 tax, as non-environmental welfare (as measured by EV) decreases. In this case, we get a significant relative reduction in emissions (larger than 6% for the largest scope of the reform) and a reduction in prices but output and income decrease. As labor costs reduce, an employment double dividend is obtained (unemployment rate decreases up to 5%).

Finally, when a SO_2 tax is compensated by reducing **IT**, we obtain the worst results for all the economic variables. First, note that non-environmental welfare (as measured by EV) monotonically decreases with the tax rate, so that no strong double dividend exists. Regarding other economic variables, although nominal GDP and YD increase when the scope of the reform is small, this increment is overpowered by a high inflation rate (ranging from 1.2 to 7.9 %), so that both variables fall in real terms. Income and output fall even in nominal terms for larger values of the environmental tax rate. Unemployment rate also increases monotonically (up to a dramatic 21.24%), so that there is no employment double dividend either. On the other hand, this reform achieves the largest emission reduction (reaching 10% for α=3), because the scale effect coming from the activity reduction adds to the substitution effect.

INSERT TABLE 2

When both reforms involving SO_2 emissions are compared (see figure 2), it is remarkable the bad behavior of unemployment (which appears again as the most sensitive variable) under the IT reform, jointly with a significant inflationary effect. Both of these variables improve under the PT reform, although in this case there is not a strong double dividend either. In return, as previously discussed, IT reform provides the largest reduction in emissions, which becomes now one of the most sensitive variables, jointly with unemployment. The important role of SO_2 emissions in Andalusia helps to understand the proportional (environmental) success obtained by aiming the tax reform at this pollutant.

INSERT FIGURE 2

5. CONCLUSIONS

In this paper, a CGE model is used to evaluate the environmental and economic effects of an ETR in the Andalusian economy, consisting of an environmental tax on CO_2 or SO_2 emissions compensated by reducing either the Income Tax or the payroll tax of employers to Social Security. The results suggest the possibility to obtain an employment double dividend when any of the environmental taxes are compensated by reducing the payroll tax. In the case of the CO_2 tax, it is also possible to obtain a (limited) strong double dividend in the sense of increasing non-environmental welfare as well as improving other economic variables, including inflation, real income and output.

Some articles in the literature find evidence supporting the employment double dividend hypothesis when an ETR involving PT is performed (see Rodríguez, 2002; Bosquet, 2000). Our results are in the same line and we can also conclude that it is crucial the way to recycle the income generated by the environmental tax. When PT is reduced it is possible to obtain an employment (or even strong) double dividend, while it is not possible when selecting the IT, which is the main direct tax in the Spanish Tax System. From this point of view, our results show that PT seems to be a very strongly distorting tax, while IT is not, in comparison with the environmental tax.

Concerning policy recommendations, our results show that an ETR involving a tax on SO_2 or CO_2 emissions and a reduction in the IT is likely to reduce pollution, and SO_2 emissions seem to be relatively more sensitive to such a reform. Nevertheless, this policy would probably generate significant economic costs, including a loss of non-environmental consumer welfare, real output and real income.

On the other hand, an ETR involving a tax on SO_2 or CO_2 emissions and a reduction in the PT is likely to get a more modest pollution cut, but will probably improve employment and, if the

CO_2 emissions are the target, a limited improvement in non-environmental welfare, economic activity (real output) and purchasing power (real income) can be expected.

Anyway, when assessing the possibility to obtain a double dividend from an ETR, two realistic general remarks, consistent with our results, should be made. Firstly, an environmental tax is a suitable instrument to improve environmental performance but, as noted by Bovenberg and de Mooij (1994), these taxes are also prone to cause further economic distortions, so that no economic improvement can be normally expected from an environmental tax itself, but any economic benefit obtained from an ETR should rather be fully attributed to the reduction in some distorting tax, which could initially be accomplished independently of any environmental policy. Secondly, and related to the first observation, the classic economic statement "there is no free lunch" also applies in this context (see, for example, Fullerton and Metcalf, 1997). Namely, it is not possible to make a reform that provides at the same time very good environmental and economic results. Typically, those reforms involving large environmental improvements (first dividend) also imply some non-negligible economic costs or, in the best of cases (if a very distorting is reduced) some small economic benefits, so that the second –strong or employment- dividend is likely to be small or even negative. On the contrary, reforms providing large economic improvements (second dividend) will normally cause, as a by-product, rises in pollution which will dwindle the first dividend.

Plausible future research lines include a more accurate analysis of the labor market and a study of the dynamic effect of this kind of reform.

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APPENDIX

PRODUCTION

Total production is given by the Cobb-Douglas technology

$$Q_j = \phi_j \left(Xd_j^{\sigma_j}, Xrow_j^{1-\sigma_j} \right) \tag{A1}$$

where Q_j is total output of sector j, Xd_j stands for domestic output of sector j, $Xrow_j$ stands for foreign output of sector j, ϕ_j is the scale parameter of sector j and σ_j (1- σ_j) is the elasticity of domestic (foreign) output.

Domestic production obtains from the Leontief production function

$$Xd_j = min\left\{ \frac{X_{1j}}{a_{1j}}, ..., \frac{X_{24j}}{a_{24j}}, \frac{VA_j}{v_j} \right\} \tag{A2}$$

where X_{ij} is the amount of commodity i used to produce commodity j, a_{ij} is the technical coefficients measuring the minimum amount of commodity i required to get a unit of commodity j, VA_j stands for the value added of sector j and v_j is the technical coefficient measuring the minimum amount of value added required to produce a unit of commodity j.

Value added in sector j is obtained from labor and capital according to a Cobb-Douglas technology:

$$VA_j = \mu_j l_j^{\gamma_j} k_j^{1-\gamma_j} \tag{A3}$$

where μ_j is the scale parameter of sector j, γ_j is the elasticity of labor, l_j represents the amount of labor employed in sector j and k_j represents the amount of capital used in sector j.

CONSUMERS

The utility function is of the Cobb-Douglas type

$$U\ (CD_j, SD) = \left(\prod_{j=1}^{24} CD_j^{\alpha_j} \right) SD^{\beta} \tag{A4}$$

where CD_j stands for consumption of commodity *j*, *SD* stands for savings of the consumer and α_j , β measure the elasticity of consumption goods and savings.

PUBLIC SECTOR

***Indirect taxes*:**

Taxes on output, R_P, are calculated as

$$R_P = \sum_{j=1}^{24} \tau_j \left[\sum_{i=1}^{n} a_{ij}\, p_i\, Xd_j + \left(\left(1 + EC_j \right) wl_j + rk_j \right) VA_j \right] \tag{A5}$$

where τ_j is the tax rate on the output of sector *j* and EC_j is the Social Security tax rate paid by employees of sector *j*.

Social Security paid by employers, R_{LF}, is given by

$$R_{LF} = \sum_{j=1}^{24} EC_j\, wl_j VA_j \tag{A6}$$

Tariffs, $R_{T,}$ equal

$$R_T = \sum_{j=1}^{24} t_j\, rowp\ a_{rwj} Q_j \tag{A7}$$

where t_j is the tax rate on all the transactions made with foreign sector *j*, a_{rwj} represents technical coefficients of commodities imported by sector *j* and *rowp* is a weighted price index of imported good and services.

Environmental tax revenue, R_{ECO}, is given by the following equation:

$$R_{ECO} = \sum_{j=1}^{24} eco_j (1+\tau_j) \left[\sum_{i=1}^{n} a_{ij} p_i Xd_j + ((1+EC_j) wl_j + rk_j) VA_j \right] + \sum_{j=1}^{24} eco_j (1+t_j) rowp \; a_{rwj} Q_j \tag{A.8}$$

where eco_j is the environmental tax on sector *j*.

The Value Added Tax revenue, R_{VAT}, is given by

$$\begin{aligned} R_{VAT} &= \sum_{j=1}^{24} VAT_j (1+\tau_j)(1+eco_j) \left(\sum_{i=1}^{24} a_{ij} p_i Xd_j + ((1+EC_j) wl_j + rk_j) VA_j \right) \\ &+ \sum_{j=1}^{24} VAT_j (1+t_j)(1+eco_j) rowp \; a_{rwj} Q_j \end{aligned} \tag{A.9}$$

where VAT_j is the tax rate *ad valorem* on (domestic and foreign) commodity *j*.

Direct taxes:

Social Security tax paid by employers, R_{LC} ,comes from

$$R_{LC} = WC \, w \, L \tag{A.10}$$

where *WC* is Social Security tax rate for employers.

Income Tax, R_I, is computed from

$$R_I = DT(wL + rK + cpi \, TPS + TROW - WC \; L \; w) \tag{A.11}$$

where *DT* is the income tax rate, *TPS* stands for transfers from Public Sector to the consumer (pensions, allowances, social benefits, unemployment benefits, …) and *TROW* stands for transfers from the rest of the world to the consumer.

Table1. ETR with CO_2 tax. Results summary. Change rate (%) with respect to benchmark levels.

Tax rate	Compensated with	Emissions	Real GDP	Real YD	Unemp. rate	EV (*)	CPI
t=0,5	PT	-0.13	0.03	0.01	-0.39	4275.6	-0.20
	IT	-0.36	-0.17	-0.17	0.77	-70441.0	0.20
t=1	PT	-0.25	0.05	0.02	-1.16	7603.4	-0.40
	IT	-0.71	-0.43	-0.43	1.54	-141208.4	0.50
t=1,5	PT	-0.37	0.08	0.03	-1.54	10011.1	-0.60
	IT	-1.06	-0.60	-0.60	1.93	-212297.9	0.70
T=2	PT	-0.49	0.08	0.02	-2.32	11526.8	-0.77
	IT	-1.41	-0.86	-0.86	2.70	-283706.0	1.00
T=2,5	PT	-0.62	0.09	0.01	-2.70	12174.7	-0.95
	IT	-1.75	-1.03	-1.03	3.47	-355428.9	1.20
T=3	PT	-0.74	0.10	0.01	-3.09	11979.4	-1.13
	IT	-2.09	-1.29	-1.29	4.25	-427463.2	1.50

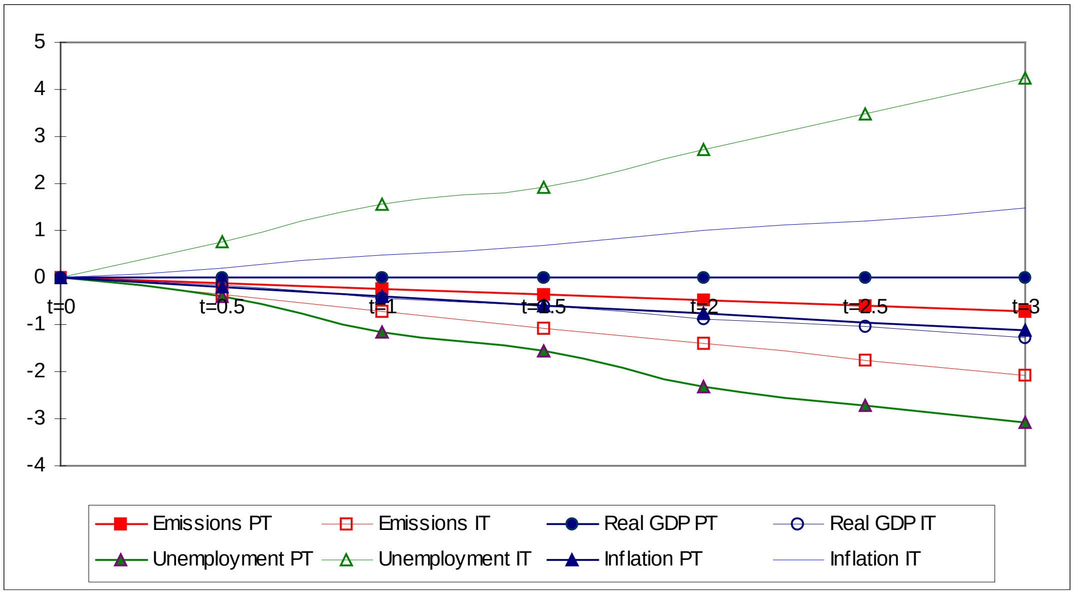
Source: own elaboration from SAMAND90 and TIOMA90.
(*): EV in thousand euros.

Table 2. ETR with SO_2 tax. Results summary. Change rate (%) with respect to benchmark levels.

Tax rate	Compens.	Emissions	Real GDP	Real YD	Unemp. rate	EV (*)	CPI
t=0.5	PT	-1.22	-0.25	-0.32	-1.54	-101012.7	-0.5
	IT	-1.95	-1.16	-1.17	3.47	-378046.8	1.20
t=1	PT	-2.37	-0.59	-0.73	-2.32	-220379.1	-0.90
	IT	-3.80	-2.30	-2.34	6.95	-764093.7	2.40
t=1.5	PT	-3.46	-1.03	-1.25	-3.47	-355697.0	-1.20
	IT	-5.55	-3.52	-3.60	10.04	-1157776.5	3.70
t=2	PT	-4.50	-1.47	-1.77	-4.25	-505087.6	-1.50
	IT	-7.22	-4.81	-4.93	13.90	-1558897.4	5.10
t=2.5	PT	-5.50	-2.01	-2.39	-5.02	-667069.3	-1.70
	IT	-8.83	-6.08	-6.23	17.37	-1967394.5	6.50
t=3	PT	-6.46	-2.66	-3.12	-5.41	-840467.9	-1.80
	IT	-10.38	-7.32	-7.52	21.24	-2383318.3	7.90

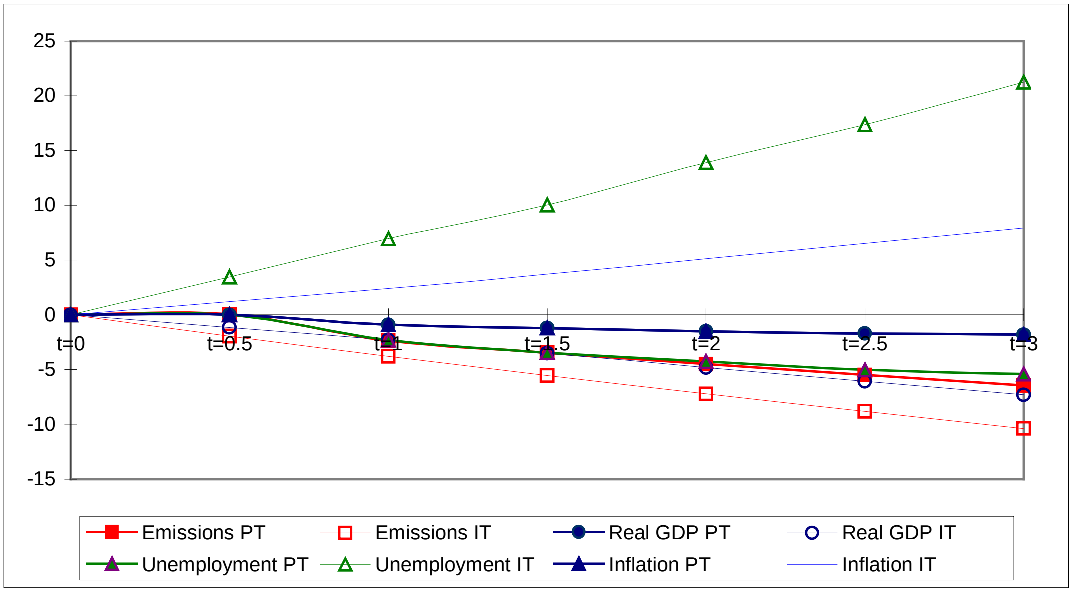
Source: own elaboration from SAMAND90 and TIOMA90.
(*): EV in thousand euros.

Figure 1. ETR on CO_2, involving a reduction in PT or IT. All variables in change rates.



Source: Own Elaboration

Figure 2. ETR on SO_2, involving a reduction in PT or IT. All variables in change rates.



Source: Own Elaboration.

Notes

[1] In the appendix the most important equations of the model are specified in detail. For further information about the model see Cardenete and Sancho (2003).

[2] The appendix specifies how every direct and indirect tax in the model is computed.

[3] In this model, the *government* includes local and regional administrations, as well as those activities of the central government in the region and any institution that is more than half financed with public funds.

[4] Labandeira et.al. (2003) use a technically different (but conceptually similar) approach, by linking pollution to energy consumption and production, and modeling the energy use decision of the producers. With such an approach, the effect of the environmental tax happens through the energy use decision. In this paper, the environmental tax acts by providing incentives to increase the production of cleaner sectors and reduce that of dirtier (energy-intensive) sectors.

[5] Agencia de Medio Ambiente, Junta de Andalucía (1996).

[6] Andalusian Ministry of Environment.

[7] According to the Andalusian Energy Program, Andalusian industries are performing a big effort to cut emissions down. By the end of the nineties, Andalusian industry had cut its emissions down to the 56% of the overall polluting emissions in the region.

[8] In 1993, the unemployment rate was 23.90% in Spain and 34.18% in Andalusia. In 2002, it was 11.36% in Spain and 19.65% in Andalusia (data from the Andalusian Statistical Institute- IEA).

[9] In fact, in the TIOMA90, SO_2 data are measured in tons, while CO_2 data are in thousand tons.

[10] Labandeira and López-Nicolás (2002) criticize the exempt minimum of 1000 tons per year, suggested by Durán and Gispert (2001) for being too high, so that, very few firms are subject to the tax. From an empirical point of view, a high exempt minimum reduces the effectiveness of the tax, while, from a theoretical point of view, it erodes the ability to restore the efficiency that was lost because of the environmental externality.

[11] Sancho (1988), in a national-level study, and Cardenete and Sancho (2002), in a regional-level one, show the distorting effects of PT on output prices and sectoral competitiveness.