PRELIMINARY VERSION
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ECONOMIC AND ENVIRONMENTAL EFFICIENT POLICIES IN AN APPLIED GENERAL EQUILIBRIUM FRAMEWORK

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ABSTRACT

The measures taken in order to fight against the climate change can create conflict when trying to achieve certain economic goals. That is why the design of economic and environmental policies can be understood as a multi-criteria decision problem. In this article we tackle the design of public policies combining multi-criteria techniques and the modeling of computable general equilibrium. More precisely, we define the "efficient policy" concept and we apply such definitions to the Spanish economy with the 2000 year data. The methodology proposed enables the construction of a set of efficient policies in terms of economic growth and polluting emissions, at the same time it enlarges the set of political goals.

Keywords: Economic policy, enviromental policy, efficiency, multicriteria decision, general equilibrium computable models
JEL: C61, C68, D78, Q58

1. Introduction

The standard approach in economics to model the optimal design of economic policy is to assume that a social planner aims at maximizing some social welfare function, typically the utility function of a representative consumer. This conventional approach is also applied to the modeLling of environmental policy, which is envisioned as the correction of externalities and other market failures in order to achieve the maximum economic welfare.

A more pragmatic look at the design of economic policy and environmental policy in practice can lead to the conclusion that policy makers do not seek to maximize a single welfare function, but they are typically concerned about a bundle of economic and environmental variables or indicators and they try to design their policies to improve the performance of the economy as measured by these indicators.

The so-called Multicriteria Decision Making (MCDM henceforth) techniques have been developed to deal with situations in which it is not reasonable or operational to assume the existence of a single criterion that rightly defines the preferences of the decision-maker (DM). This type of approach has been applied very extensively to the management of the environment and natural resources (see e.g., Romero and Rehman, 1987, Mendoza and Martins, 2006, Mavrotas and others, 2006, Brody and others, 2006, Liu, 2007, Noble and Christmas, 2008).

In a recent line of research, André and Cardenete (2005, 2007) and André, Cardenete and Romero (2007) have proposed the use of MCDM techniques for the design of macroeconomic policies. We build on this line of research, but we enlarge it by including, not only economic, but also environmental objectives. In this way we aim at providing a broader framework to envision jointly economic and environmental policies.

The key elements to apply this approach are the following: first, a model or mathematical representation of the economic under analysis, including both economic and environmental variables. We resort to a Computable General Equilibrium (CGE) model. This kind of models has been extensively used for the empirical analysis of both economic and environmental problems (André and others, 2005, O'Ryan and others, 2005, Böhringer and Löschel, 2006).

Second, the policy making problem must be set-up by defining the relevant policy objectives and the policy instruments. In this paper, we start with a bi-criteria problem including just one economic objective (increasing output growth) and one environmental objective (reducing CO_2 emissions). In a second step, we increase the scope of the problem by including some additional economic objectives.

The third element is a multicriteria technique capable of dealing with the decision problem. In this paper we use multiobjective programming, which is a methodology designed to look for so-called *efficient policies*. Iin a multicritera framework, a solution is said to be efficient if it is not possible to find another solution which improves the value of some objective without worsening the value of any of them. In our context, following André and Cardenete (2008) we define a policy (i.e., a combination of the policy instruments) as efficient if there is not any other policy providing a better value for some policy objective without being worse for any other policy objective. The main motivation to find efficient policies is that every objective is reached with the minimum loss for the other relevant objectives. For example, any measure adopted to improve the quality of the environment will be easier to implement and to be accepted by society if they do not imply a severe reduction in economic growth, a large increase of public deficit, a very high inflation rate and so on. On the other hand, it is also reasonable to prosecute economic targets with the minimum possible emissions. The methodology is applied to the Spanish economy.

In section 2 we present the model. In section 3 we describe how the policy design exercises are constructed. In section 4 we present the first problem with only two objectives, which are enlarged to 5 in section 5. Section 6 concludes.

2. The model and the databases

2.1. The basic model

We use a CGE model following the basic principles of the Walrasian equilibrium. See Kehoe and others (2005) for an up-to-date review of this kind of models. Our model is enlarged by including both public and foreign sectors and explicitly accounting for polluting emissions. Taxes and the activity of the public sector are taken as exogenous by consumers and firms, while they are considered as decision variables by the government. The activity level of the foreign sector is assumed to be fixed, in the sense that the total amount of imports and exports is not sensitive to the policy changes implemented by the government. This assumption is consistent with a short run approach for policy design.

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 maximising her utility. On the other hand, it is assumed that the productive sectors are maximising their profits (net of taxes), public income equals the payments of all economic agents, and supply equals demand in all markets. In order to save some space, we just discuss some of the main elements of the model. Some additional details can be found in André et al. (2005).

The model comprises 9 productive sectors, after aggregation of the 1995 Social Accounting Matrix (SAM) of Spain. The production technology is given by a *nested production function*. The domestic output of sector j (j=1,...,9), measured in euros and denoted by Xd_j, is obtained by combining, through a Leontief technology, outputs from the rest of sectors and the value added VA_j. In turn, this value added is generated 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, R, (the appendix specifies how every tax in the model is computed) as well as it gives transfers to the private sector, TPS, and demands goods and services from each sector $j=1,...,9$, GD_j. PB denotes the final balance (surplus or deficit) of the public budget:

$$PB = R - TPS\ cpi - \sum_{j=1}^{9} GD_j\ p_j \tag{1}$$

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 all taxes, including environmental taxes.

There is only one foreign sector, which comprises the rest of the world. The balance of this sector, $ROWD$, is given by

$$ROWD = \sum_{j=1}^{9} rowp\ IMP_j - TROW - \sum_{j=1}^{9} rowp\ EXP_j \tag{2}$$

where IMP_j denotes imports of sector j, EXP_j exports of sector j, $TROW$ transfers from abroad for the consumer and $rowp$ is a scalar price index for the foreign sector calculated as a weighted average of all traded goods and services (including both imports and exports).

Final demand comes from investment, exports and consumption demand from households. In our model, there exist 9 different goods –corresponding to productive sectors- and a representative consumer who demands present consumption goods and saves the remainder of her disposable income. Consumer disposable income (YD henceforth) equals labor and capital income, plus transfers, minus direct taxes:

$$YD = w\,L + r\,K + cpi\;TPS + TROW - DT\,(r\,K + cpi\;TPS + TROW) - DT\,(w\,L - WC\,w\,L) - WC\,w\,L \tag{3}$$

where w and r denote input (labor and capital) prices and L and K input quantities sold by the consumer, DT is the income tax rate and WC the tax rate corresponding to the payment of the employees to Social Security. The consumer's objective is to maximise her welfare, subject to her budget constraint. Welfare is obtained from consumption goods CD_j (j = 1,…, 9) and savings SD, -according to a Cobb-Douglas utility function:

$$\begin{aligned} &\text{maximize} && U\,(CD_1,\ldots,CD_9,SD) = \left(\prod_{j=1}^{9} CD_j^{\alpha_j}\right) SD^{\beta} \\ &\text{s.t.} && \sum_{j=1}^{9} p_j CD_j + p_{inv}\,SD = YD \end{aligned} \tag{4}$$

where p_{inv} is an investment price index and α_j and β represent the elasticities of utility with respect to the consumption of good j and savings respectively. For the sake of normalization it is assumed $\sum_{j=1}^{9} \alpha_j + \beta = 1$.

Regarding investment and saving, this is a *saving driven* model. The closure rule is defined in such a way that investment, INV, 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:

$$\sum_{j=1}^{9} INV_j\,p_{inv} = SD\,p_{inv} + PB + ROWD \tag{5}$$

Labor and capital demands are computed under the assumption that firms aim at maximising profits and minimising the cost of their production. In the capital market we consider that total supply is perfectly inelastic. In the labor market, we use the following approach for the labor supply, which shows a feedback between the real wage and the unemployment rate, related to the power of unions or other factors inducing frictions in the labor market (see Kehoe *et al.*, 1995):

$$\frac{w}{cpi} = \left(\frac{1-u}{1-\bar{u}}\right)^{\frac{1}{\beta}} \tag{6}$$

where u and $\bar{u}$ are the unemployment rates in the simulation (after some specific policy is implemented) and in the benchmark equilibrium (i.e, the observed value in 1995) respectively, w/cpi is the real wage and β is a flexibility parameter. This formulation is consistent with an institutional setting where the employers decide the amount of labor demanded and workers (represented by trade unions) decide real wage taking into account the unemployment rate according to equation (6). If labor demand increases (decreases), the unemployment rate u decreases (increases); as a consequence, there are less (more) available workers, who enjoy now more (less) bargaining power and enables them to demand higher (lower) real wages. If, after the simulation, employment remains unchanged, the real wage will be the same as in the benchmark equilibrium. Concerning the value of the flexibility parameter, it cannot be calibrated using the SAM, because this database does not include data about unemployment. For the empirical exercises, we take β=1.

2.2. Pollution and environmental taxes

We focus on CO_2 emissions obtained from production activities and we adopt a short-term approach. The production technology is assumed to be fixed and so is the pollution intensity of all the sectors. Let E_j denote emissions from activity sector j ($j = 1,\ldots,9$). Then, we have the following equation, which assumes a linear relationship between production Q_j (measured in constant euros) and emissions:

$$E_j = \alpha_j \cdot Q_j \tag{7}$$

where α_j measures the amount of emissions per unit of output produced in sector j. The technical parameter α_j accounts for the differences in pollution intensities across sectors. This formulation overlooks abatement or technical change possibilities by implicitly assuming that pollution intensity is given. In other words, firms can reduce emissions only by cutting down production. This simplification is perhaps not realistic in the long run, but it is consistent with a short-run setting, in which technology is given and substitution possibilities are limited.

We include the possibility that the government can impose an environmental tax of t euros per unit of emissions. As a consequence, because of its emissions, each sector j pays T_j euros, where

$$T_j = t \cdot E_j \tag{8}$$

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 (7) into (8), the tax to be paid by sector j can be written as

$$T_j = \beta_j \cdot Q_j \tag{9}$$

where $\beta_j \equiv t \cdot \alpha_j$ is the tax rate of sector j in terms of euro paid per euro produced because of its emissions. Henceforth, from the viewpoint of the industry, the impact of an environmental tax is similar to that of a unit tax on output, with the particularity of having a higher tax rate for more polluting industries. The tax will create a wedge between the price paid by consumers and the price received by firms. We can expect that equilibrium (consumer) price will increase and equilibrium quantity will decrease. The tax creates a negative incentive for production (and hence, for pollution), which is particularly strong for more intensively polluting sectors. So, we can expect that output will decrease more in those sectors. The final impact on total output, employment and prices will be the aggregation of all the sectoral effects.

The total amount of emissions E, equal the sum of the emissions generated by all the sectors:

$$E = \sum_{j=1}^{9} E_j \tag{10}$$

2.3. Databases and calibration

The main economic data used in the paper come from the aggregated 2000 social accounting matrix (SAM) for Spain, which is the most recent officially available. It comprises 21 accounts, including 9 productive sectors (1 Agriculture, cattle, forestry and fishing, 2 Extractives, 3 Energy and Water, 4 Food, 5 Chemicals, 6 Machinery and transport, 7 Manufactures, 8 Construction, 9 Services), two inputs (labour and capital), a saving/investment account, a government account, direct taxes (income tax and Social Security employees contribution) and indirect taxes (VAT, payroll tax, output tax and tariffs), a foreign sector and a representative consumer.

The values for the technological coefficients, the tax rates and the coefficients of the utility function are calibrated to reproduce the 2000 SAM as an initial or benchmark equilibrium for the economy. In the simulations, the wage is taken as numeraire (w = 1) and the rest of prices vary as required to meet equilibrium conditions.

In order calibrate the α_j coefficients, we also use data by sector from the Satellite Accounts on atmospheric emissions of the Spanish Statistical Institute (INE).

3. Setting the policy design exercise

In order to have our policy design exercise totally defined, we need to choose the policy instruments and the policy objectives.

Regarding *policy instruments*, we focus on fiscal policy. Therefore, we consider as policy instruments, taxes and public expenditure. Concerning taxes, we assume that the government uses as policy instruments the average rate of the following taxes:

DIRECT TAXES

- Income tax
- Social security contribution of employees

INDIRECT TAXES

- VAT (allowing for a different tax rate in each activity sector)
- Payroll tax (allowing for a different tax rate in each activity sector)

ENVIRONMENTAL TAXES

- Tax on CO_2 emissions.

Concerning expenditures, we consider that the government can decide the volume of public expenditure in each activity sector.

For the sake of realism, we also include some constraints for the feasible values of the policy instruments. Specifically, we assume that all the instruments cannot vary more than 5% with respect to the real value observed in 2000. If we denote by x the vector of tax rates and expenditures by sectors, and by x_0 the observed valued of those variables in 2000, we include the following set of constraints:

$$0.95x_0 \leq x \leq 1.05x_0$$

On the other hand, in order to avoid very unrealistic solutions in terms of the public budget, although we allow that the public expenditure varies 5% by sector, we require that total expenditure remains equal to the observed value in 2000. Concerning the tax rate of the emissions charge, we set a lower bound equal to 0 (meaning that pollution cannot be subsidized, although we account for the possibility that not tax is imposed) and an upper bound equal to 0.02 euros per unit of pollution (kton/year of CO_2 emissions). The upper limit is set in order to avoid that the tax burden is excessively high in terms of output.[1].

Concerning policy objectives, we present two different policy design exercises. The first one (presented in section 4) is a bi-objective problem, assuming that the government is only concerned about two objectives. The first is to foster economic activity as measured by the yearly growth rate of real Gross Domestic Product (GDP), denoted as g_Q:

$$g_Q \equiv \frac{GDP_{2000} - GDP_{1999}}{GDP_{1999}} 100 \tag{11}$$

where GDP_{1999} is the Gross Domestic Product of 1999 which is taken as a given exogenous value. The GDP of 2000 results from aggregating output across sectors. Since GDP_{1999} is given, maximizing growth is equivalent to maximizing GDP_{2000}. We chose the former because it is a more common indicator in practice.

The second objective is to reduce CO_2 emissions. Specifically, we include as a policy objective the growth rate of emissions with respect to the observed value in 2000 (the idea is to measure by how much we could reduce emissions by changing policy as compared to what was observed in reality, i.e., without doing any change):

$$g_E = \frac{E - E_{obs}}{E_{obs}} \cdot 100 \tag{12}$$

where E is the value of emissions resulting from the equilibrium of the model and E_{obs} is the observed 2000 value.

[1] Specifically, when the environmental tax rate is set at its highest rate, the most polluting sector (whic is sector 7, “Production and distribution of electricity”) has an average tax rate of 8% in terms of output.

Later on (in section 4), we seek a more realistic exercise by including some additional economic objectives, such as unemployment, public deficit and fiscal pressure.

4. Efficient policies regarding growth and emissions

As a first approach to the design of efficient policies, we assume that the government is concerned only about two policy objectives: increasing growth and reducing CO_2 emissions.

Table 1 displays the so-called *payoff matrix*, which is obtained by optimizing each objective separately. Thus, the values of the first row represent the solution which is obtained when growth is maximized without taking into account the environmental consequences. In such an optimization problem, apart from the constraint on the policy instruments, we include all the equations of the CGE model in order to guarantee that the solution is consistent with the model (i.e., that the observed values correspond to an economic equilibrium). We conclude that, if the government designed its policy just to maximize growth, it would be possible to get a growth rate equal to 4.94 %. Nevertheless, this policy would imply, as a side-effect, a volume of CO_2 emissions equal to 280,265.23 kton/year, which means an increment of 0.59 % with respect to the observed value in 2000.

Table 1

Payoff matrix growth-CO_2 emissions

	g_Q, *Econ. Growth* (%)	g_E, *Emis. Growth* (%)
Max g_Q	4.94	0.59
Min g_E	3.45	-2.01

If, on the other hand, the government devoted all its efforts to control pollution, it would be possible to obtain 274.627,82 kton/year CO_2 emissions, which means a reduction of about 2% with respect to the observed value. The economic consequence of this policy would be an economic growth rate of 3.45 %, i.e., about 1.5 below the maximum feasible value (see the second row of Table 1). Therefore, we conclude that there is a conflict between both objectives, in the sense that it is not possible to get at the same time the optimal value for both.

By comparing the value of the policy instruments in both solutions, we conclude (as one could expect) that maximizing growth is consistent with fixing the environmental tax rate at its lower bound, zero. On the other hand, the emissions minimizing solution entails setting the highest possible value of this tax (0.02 € per kton/year of emissions). Moreover, maximizing growth also requires reducing the rest of indirect taxes (VAT and payroll tax) whereas minimizing emissions requires increasing them. Additionally, both solutions entail increasing direct taxes (income tax and social security of employees). Finally, the growth maximizing solution requires shifting public expenditures to sector 17 ("vehicles") and minimizing emissions is consistent with increasing public expenditure in sector 25 ("other services"), which is one of the less polluting.

The next step is to construct the set of efficient policies. The idea is to get any level of economic growth with the minimum value of emissions or, alternatively, to achieve environmental goals with the maximum feasible growth. We perform this task using the so-called *constraint method*, by optimizing an objective while setting a parametric limit for the other one (it is an arbitrary decision which one is used as an objective or as a constraint). Specifically, we have used the following procedure: the feasible values of g_E range between -2,01% and 0,59%. We make a grid within this range. In this case, ten values turn out to be enough for a good approximation of the efficient set. Let g_{E_n} (n=1,…,10) denote the n-th value of the grid. For each of those values, we solve the problem of maximizing growth imposing that emissions are not greater than g_{E_n}, i.e.,

$$\begin{aligned} &Max\, g_Q \\ &s.t. \\ &\quad g_E \leq g_{E\_n} \end{aligned} \tag{13}$$

and all the equations of the CGE model. By construction, each of these problems provides an efficient solution. The results of these calculations are shown in Figure 1.

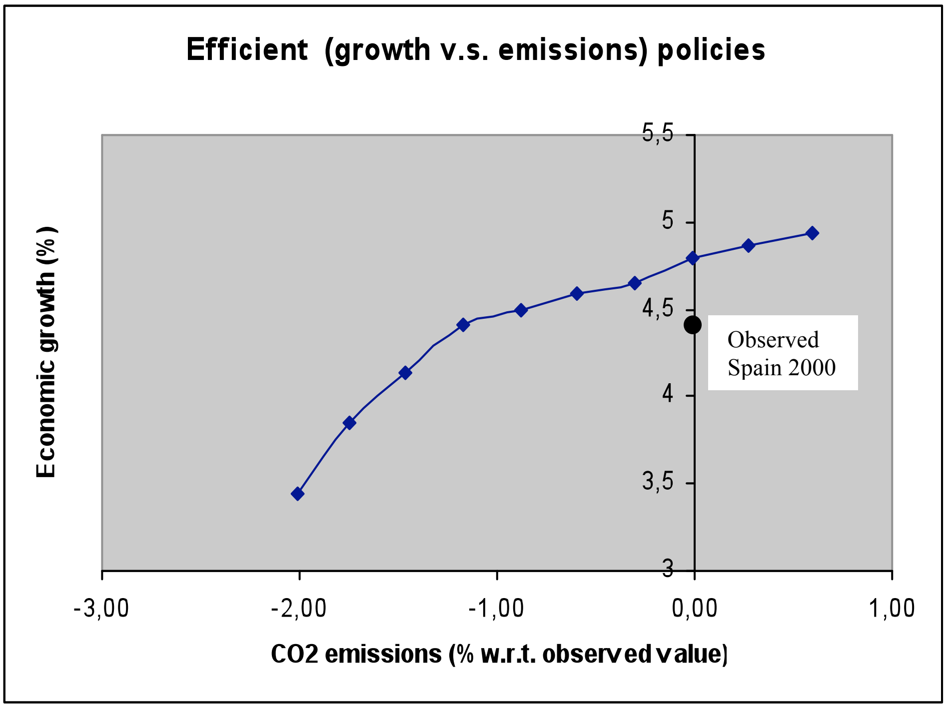

Figure 1

The first conclusion we can get from Figure 1 is that the relationship between both variables is monotonically increasing, i.e., the higher the level of emissions the government is willing to accept, the higher the growth rate that can be reached. Or, symmetrically, tougher environmental targets imply lower growth rates.

As an additional insight, note that the slope of the efficient frontier is not constant. Indeed, the slope is higher for low values of emissions than for higher values. The interpretation of this result is that, as the government pursues higher growth levels, the marginal cost in terms of additional emission increments is increasing. Or, symmetrically, setting tougher environmental goals entails increasing costs in terms of reductions in the growth rates.

Figure 1 also displays the observed combination of growth and emissions in Spain 2000, i.e, g_E =0 (by construction) and g_Q =4.4 (source: INE[2]). Note that the observed combination is strictly below the efficient frontier. This seems to suggest that the policy actually followed by the government could be improved in terms of efficiency if we restrict to the two policy objectives considered here. Actually, by choosing an alternative combination of the policy instruments, it would be possible to get about 0.4 additional points of growth with the same emissions. Alternatively, it would also be possible to have the same growth rate while reducing emissions about 1% below the observed value.

[2] Spanish Statistical Institute.

Figure 2 shows the value of the emissions charge throughout the efficient frontier. As expected, tougher environmental goals monotonically entail higher environmental tax rates. As a matter of fact, if we want to cut down emissions more than 1%, the model recommends to set the tax rate at its highest feasible value. Softer environmental goals are consistent with lower tax rates and, as the policy preferences move towards maximizing growth (while disregarding pollution), the optimal emissions charge tends to zero.

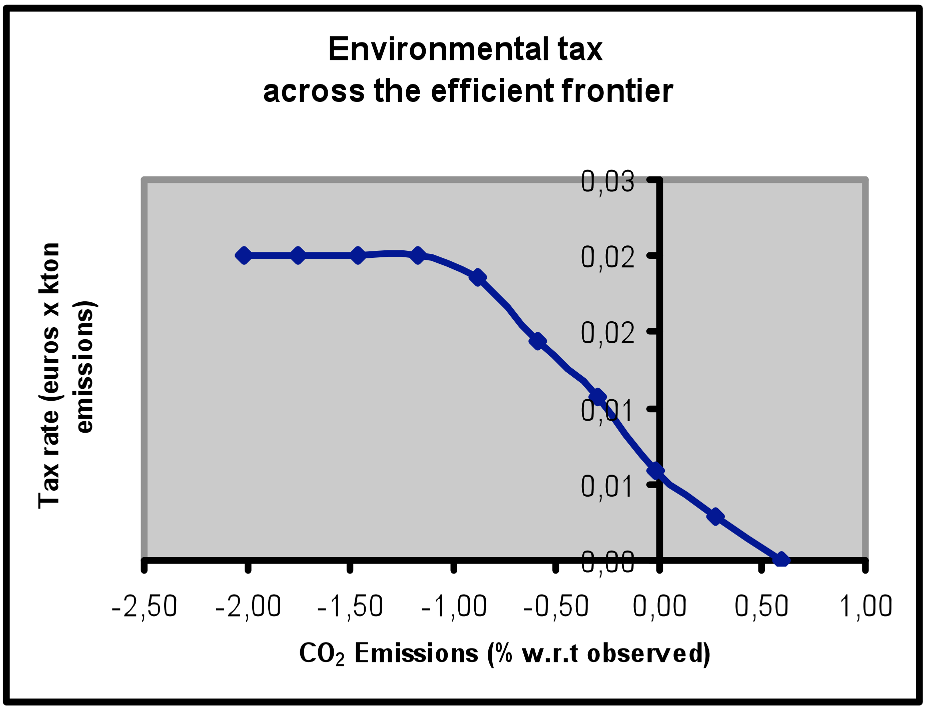

Figure 2

5. Efficient policies with more than two criteria

In the previous section, we have made the simplifying assumption that the government is concerned about a single economic objective, namely, real growth. The aim of this section is to design a more realistic exercise by including some additional economic objectives. Specifically, we include unemployment, u , public deficit, *PD*, and fiscal pressure, *FP*, defined as total tax collections as a percentage of GDP. We assume that the government aims at minimizing the value of all these three objectives.

Table 2 represents the new payoff matrix with the added criteria. As before, each row displays the results of a monocriterion problem involving the optimization of a single objective disregarding the rest. The numbers in the main diagonal (in bold characters) are the optimal values of all each objective and they altogether represent the so-called *ideal point*. In each column, the worst value for each objective (the minimum growth rate, the maximum increment in emissions, and so on) is displayed underlined. All these values jointly represent the so called *anti-ideal or nadir point*.

Table 2

Payoff matrix with 5 objectives

	g_Q (%)	g_E (%)	u (%)	PD (10^6 €)	FP (%)
Max g_Q	4,94	<u>0,59</u>	13,10	17.588	33,06
Min g_E	<u>3.45</u>	-2,01	<u>15,28</u>	<u>24.545</u>	<u>34,84</u>
Min u	4,94	0,56	13,09	17.680	33,05
Min PD	4,05	-0,79	14,41	13.817	<u>34,84</u>
Min FP	4,44	0,16	13,83	16.023	32,96

From Table 2 we can draw the following conclusions: firstly, maximizing growth and minimizing unemployment (first and third objectives) seem to be fully consistent with each other, since both monocriteria problems provide essentially the same solution (with tiny, irrelevant numerical differences). Therefore, the same degree of conflict that exists between emissions minimization and economic growth (see section 3) also exists between emissions minimization and unemployment minimization. Actually, minimizing unemployment entails an 0.56 % increment of emissions while minimizing emissions leads to the worst possible value of unemployment, with 2 percent points above its ideal value. On the other hand, the second row shows that emission minimization seems to display a strong conflict with all the economic objectives since all of them achieve their anti-ideal values.

A more detailed analysis reveals that the conflict between polluting emissions and public deficit is not so straightforward as it may seem at first sight. While minimizing public deficit is compatible with a noticeable reduction of emissions (-0.79 %), if from this point one tries to further reduce emissions to reach their minimum value, this additional effort will bring a strong increase of public deficit up to 24,545 million euros, which represents more than a 70% increment over its ideal value. These results suggest the existence of a non-monotonic relationship between both variables. A similar conclusion can be obtained about the relationship between emissions and fiscal pressure. Figure 3 shows the behaviour of unemployment, public deficit and fiscal pressure in different points of the growth-emissions frontier displayed in Figure 1. Notice that, while the environmental goal gets softer (and the economic growth objective becomes more demanding) the unemployment results improve. Nevertheless, this movement does not have a uniform effect on public deficit and fiscal pressure.

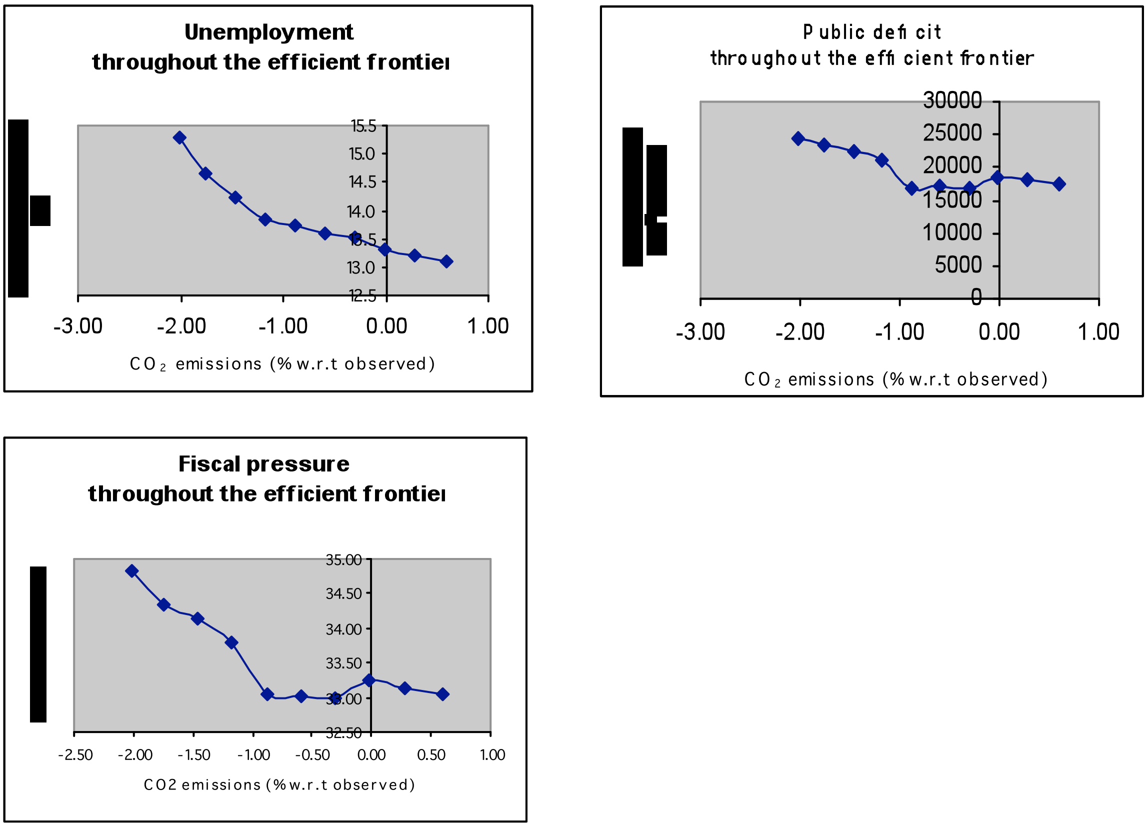

Figure 3

On the other hand, in Table 2 we can also observe that, to some extent, there is also some conflict among economic objectives. The most noticeable case is public deficit, the minimization of which involves almost 1 point below the ideal value of growth, more than one additional point of unemployment with respect to the minimum attainable value and, as one could expect, a high value of fiscal pressure.

As a summary of these observations, we can conclude that economic growth cannot be taken as an adequate indicator of all the relevant economic objectives of policy makers. Moreover, the relationships among different policy objectives are by no means trivial and, in order to get meaningful results in terms of all the objectives, all of them should be explicitly incorporated in the policy design problems.

Enlarging the set of policy objectives necessarily increases the dimension and the complexity of the problem. Typically, the increased dimension also brings an exponential increment in the number of efficient solutions. Such a problem can be handled with different computational techniques. Our aim here is not to offer a systematic exploration of the efficient set, but simply to illustrate the use of alterative techniques which could be used by policy makers to find their own efficient solutions.

Thus, we present two alternative ways to tackle this multi-objective problem. The first possibility is to use again the *constraint method*. This can be done by optimizing a single objective while keeping all the rest limited by parametrical constraints. As a first approximation, we will take as parametrical limits the observed values in Spain 2000 for each of the objectives:

$g_Q = 4.4$ % $g_E = 0$ % $u = 14.0$ % $PD = 15957$ mill. € $FP = 33$ %.

Firstly, we solve the following problem, which involves maximizing growth while restricting the rest of objectives to get a value which is not worse than the observed values:

$$\begin{aligned} &Max\ g_Q \\ &\text{s.t.} \quad g_E \leq 0,\ u \leq 14.0, PD \leq 15{,}957, FP \leq 33 \\ &\qquad \textit{and all the equations of the CGE model} \end{aligned} \tag{14}$$

After solving this problem, we get the following values for all the policy objectives (also shown in the first row of Table 3):

$g_Q = 4.67$ $g_E = 0$ $u = 13.48$ $PD = 15{,}957$ $FP = 32.86$

Note that this solution Pareto-dominates the observed situation since we get, at the same time, a higher growth rate and lower unemployment and fiscal pressure, while polluting emissions and public deficit remain at the same values. The mere existence of this solution implies that the observed policy is inefficient with respect to these five objectives, given the feasible set of policy instruments.

By doing similar calculations for each objective, we get the solutions displayed in Table 3. The second row of this table shows that, with the same growth as observed in 2000, it would be possible to reduce emissions about 1% below the observed value. Moreover, this solution would not imply any increment of public deficit and would provide, as by-products, a slight reduction in unemployment and fiscal pressure. Similar conclusions can be obtained from the other rows of Table 3.

Table 3

Constraint method with 5 objetives

	g_Q (%)	g_E (%)	u (%)	PD (10^6 €)	FP (%)
Max g_Q	4.67	0.00	13.48	15,957	32.86
Min g_E	4.40	-1.03	13.86	15,957	32.90
Min u	4.46	0.00	13.48	15,878	32.96
Min PD	4.40	-0.54	13.88	14,578	32.74
Min FP	4.40	-0.47	13.88	15,054	32.74

These calculations provide a first approximation to the set of efficient policies. Nevertheless, when using the constraint method, efficiency is guaranteed only if all the parametric constraints are binding in the solution. Although all the solutions in Table 3 Pareto-dominate the observed one, in all of them there are some constraint(s) which is (are) not binding. Therefore, we cannot be sure that these solutions are efficient. A possible way to get efficient solutions is to make all the constraints tougher by increasing the limit of the "more is better" constraints and reducing the limit of the "less is better" constraints until we get a solution in which all of them are binding. A sensible way to make this adjustment procedure is to take into account the preferences of the policy maker over all the objectives. Another approach to get efficient solutions is to use the so-called *weighting method*. This method works by optimizing a weighted average of all the normalized objectives. This can be done by maximizing the following objective function:

$$\omega_Q \frac{g_Q - g_{Q*}}{g_Q^* - g_{Q*}} + \omega_E \frac{g_{E*} - g_Q}{g_{E*} - g_E^*} + \omega_u \frac{g_{u*} - g_u}{g_{u*} - g_u^*} + \omega_{PD} \frac{g_{PD*} - g_{PD}}{g_{PD*} - g_{PD}^*} + \omega_{FP} \frac{g_{FP*} - g_{FP}}{g_{FP*} - g_{FP}^*} \qquad (15)$$

where X^* represents the ideal value and X_* the anti-ideal value of objective X, as displayed in Table 3. Since the objectives are measured in different units, they cannot be aggregated if they are not normalized. Such normalization can be done using the difference between the ideal and the anti-ideal values. The individual ratios shown in equation (5) are bounded between zero (when the anti-ideal value is reached) and one (when the ideal is attained) by construction. The weighting coefficients ω_i are preference parameters measuring the importance given to each objective by the policy maker. As an example, assume that the policy maker considers that all the objectives are equally important and therefore all the weights are equal. Maximizing function (5) given this symmetric weighting provides the following value for the objectives:

$$g_Q = 4.42 \qquad g_E = -0.9 \qquad u = 13.83 \qquad PD = 14552 \qquad FP = 32.69$$

Note that this solution Pareto-dominates the observed one since it provides better values for all the objectives and it is efficient by construction. By using different combinations of the weighing parameters, it is possible to find different efficient policies corresponding to different preferences of the decision maker. As extreme cases, if w_i =1 for a single objective *i* and w_j =0 rest, we can represent a situation in which the policy maker is concerned just about objective *i* and does not care about the rest. The resulting problem is a mono-criterion optimization problem as the ones solved to get the payoff matrix.

6. Conclusions

Both economic and environmental objectives are relevant for the design of public polices. The concept of *efficient policies* allows us to represent in a simple way the idea that we want to get as good as possible results for each objective while assuming the lowest possible loss in terms of the other objectives.

Including environmental together with economic objectives in a policy design under a CGE model is a methodological novelty with respect to previous works. Another novelty (this time a statistical one) is to use the recently developed SAM for Spain 2000.

After calibrating our model for the Spanish economy, we can build an approximation to the set of efficient policies once the relevant objectives have been chosen. This way, we can get an estimation of the sacrifice that every environmental goal entails in terms of reduced economic growth. It is also possible to determine in which direction the policy mixed should be reformulated in order to get efficient combinations of economic activity and environmental impact.

Our results show that a properly reoriented policy (basically by reducing indirect taxes, while increasing direct taxes and shifting public expenditures to some specific sectors) it would be possible to get a growth rate around 5% although this would accept that polluting emissions would be 0.6% higher with respect to the benchmark value. On the other hand, an agressive *green* policy could render 2% less of emissions if the policy makers are willing to accept a lower economic growth rate. This could be done by taxing emissions and rising other taxes together with a reorientation of public expenditure from very polluting to low polluting sector such as “other services”.

By comparison with the efficient frontier, the observed policy in Spain 2000 could be reformulated to provide the same level of economic activity with 1% less of emissions or, alternatively, to growth 0.4 more with the same CO_2 emissions.

We have also shown how this model can be enlarged to include more than two objectives. This enlargement complicates the computations and also provides a higher degree of realism.

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