"REFORMAS DE IMPUESTOS MEDIOAMBIENTALES Y LA MITIGACIÓN DEL EFECTO REBOTE: LA EVALUACIÓN DE UN POSIBLE TERCER (CUARTO) DIVIDENDO"

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Resumen

Este análisis presenta evidencia empírica sobre los posibles efectos sobre toda la economía de las Reformas de Impuestos Medioambientales así como de políticas "híbridas" que suponen la combinación de estas con las políticas de eficiencia energética. Con este objetivo se ha utilizado un Modelo de Equilibrio General Aplicado para la Economía Española. Nuestros resultados indican que existen ciertas complementariedades entre éstas políticas. Su simultánea aplicación podría reforzar la posibilidad del primer dividendo (reducción en el nivel de emisiones de CO_2), del segundo dividendo (un aumento en los niveles de bienestar de toda la economía) , del tercer dividendo (un incremento en los niveles de empleo) e incluso-un cuarto dividendo (la mitigación del efecto rebote que erosiona la eficacia de las políticas de eficiencia energética). Se ha evaluado dos tipos de de Reformas de Impuestos Medioambientales. El primer tipo de reforma supone la compensación del aumento en los impuestos medioambientales con reducción en las contribuciones de la seguridad social pagadas por el empleador. El segundo tipo de reforma, sin embargo, compensa ese aumento con caídas en los impuestos indirectos sobre la producción doméstica. Estas dos políticas alternativas no han sido seleccionadas *ad-hoc*. Estos dos impuestos se seleccionaron después de utilizar una metodología novel que permitía evaluar los posibles efectos interactivos entre impuestos. El tamaño de estos efectos ha sido considerado relevante para determinar los efectos a nivel de toda la economía de las Reformas de Impuestos Medioambientales. De acuerdo con nuestros resultado, las contribuciones a la seguridad social pagadas por los empleadores serían un buen candidato para llevar a cabo este tipo de políticas en el caso español ya que presentaban efectos interactivos mucho mayores que el resto de los impuestos considerados.

"GREEN TAX REFORMS AND THE MITIGATION OF THE REBOUND EFFECT: THE EVALUATION OF A LIKELY FOURTH DIVIDEND"

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Summary

This analysis presents empirical evidence about the possible economy-wide impacts of Green Tax Reforms as well as of "hybrid" policies that combine them with energy efficiency policies. In doing so we have used a static applied General Equilibrium Model for the Spanish economy. Our results indicate that there are some complementarities between Green Tax Reforms and energy efficiency policies. In fact, according to our results, the simultaneous implementation of these policies might reinforce the likelihood of the first dividend (a reduction in CO_2 emissions levels), the second dividend (an increase of overall efficiency levels in the economy) and the third dividend, i.e. the employment dividend, while mitigating the economy-wide rebound effects from energy efficiency policies—*the fourth dividend*. We evaluate two types of Green Tax Reforms. The first one compensates the increases in environmental taxes with declines in the social security contributions paid by employers. The second one considers that these increases go with a reduction in the indirect taxes on domestic production. These two likely Green Tax Reforms have not been chosen *ad-hoc* but rather using a novel approach that allows computing the tax interaction effect. This effect is considered as a key issue on determining the derived economy-wide impacts of this type of policies. Our findings indicate that the social security contributions paid by employers lead to the largest tax interaction effects and consequently they are appropriate candidates for Green Tax Reforms in the Spanish economy.

I. INTRODUCTION

Due to the existing perverse relationship between economic activity and environmental degradation, those policies that could potentially weaken these interdependencies have been getting increasing attention. This is specially the case in industrialized countries. As a consequence, environmental and energy policies seek to promote a much more sustainable economic development.

Among these policies, tax policies specifically targeted on non-clean goods have attracted much interest by governments and policy makers. An example of their great relevance in the actual context is the role that these policies played in the process of the European economic integration[1]. Nowadays, the European Union (EU) is the worldwide leader in the application of these market instruments to mitigate the level of pollutants in the atmosphere that reduced environmental quality, i.e CO_2 and NO_x. According to the published figures, in 2007 the percentage that taxes of this type represented over the EU PIB and overall taxes were, respectively, 2.45 and 6.16 percent. Furthermore, the Commission Green Paper[2] (2006) calls our attention to the relevance of environmental taxes not only for the process of fiscal harmonization in the European territory but also for favouring the degree of effectiveness of other energy policies such as those that promote the use of renewables and energy efficiency.

The rationale of environmental and energy taxes stems from the Pigouvian theory (Pigou, 1920). These taxes are charged over the final and intermediate consumption of those products that generate the emission of pollutants to the atmosphere, therefore contributing to climate change. To "get prices right", environmental or green taxes, i.e. taxes on emissions levels and energy, should reflect marginal damages and thus equalise prices to marginal social costs. The objective of these taxes is then to make agents "artificially internalize" the negative externality. This price policy allows reaching social optimum level of emissions.

[1] Council Directive 2003/96/EC of 27 October 2003 restructuring the Community framework for the taxation of energy products and electricity. OJ L 283/51, 31.10.2003. This Directive was revised in March 2007 including an increase in the taxes charged on energy products used for transport.

[2] See "Commission Green Paper: A European Strategy for Sustainable, Competitive and Secure Energy". March 2006.

Economic policies implemented via prices present some advantages vis a vis other possible instruments that seek to protect environmental quality. Taxes reduce the uncertainty about the costs derived from getting the policy objectives. They are effective in changing agents' behaviour, are easy to execute and generate "extra" revenues—a welcome hand in the administration and control of the public deficit. Additionally, these "extra" revenues might be used to reduce other distortionary taxes. The later statement becomes relevant when considering the Double Dividend Hypothesis (DDH) (Terkla, 1984; Lee and Misiolek, 1986; Pearce, 1991; Repetto et al. 1992; and Poterba, 1993) All these advantages, and specially the possibility of favouring both reduction of emissions levels (first dividend) and the overall efficiency of the economy tax system (second dividend), might explain why the EU have been promoting the application of what has been called Green Tax Reforms (GTR) in the literature.

Nowadays, many European countries have embarked on GTR, i.e. Sweden (1990), United Kingdom (1996), Netherlands (1996), Germany (1999) and Norway (1999. Differently to these countries, Spain has not yet applied this policy measure, perhaps because of the belief that taxes, in general, might negatively affect economic growth. Additionally, the empirical results obtained for the Spanish economy when trying to evaluate GTRs has been quite controversial (Labandeira et al, 2004; Manresa and Sancho, 2005**).** Applying the same methodological tool, a static CGE model for the Spanish economy we also explore in this analysis the reasons that might explain the different findings in the aforementioned studies. Furthermore, we extend previous GTRs scenarios considering additional revenue-recycling possibilities, such as indirect taxes on domestic production as a companion result of increasing environmental tax rates.

Another contribution of our analysis has been to compute the so-called tax interaction effect for the most distorting tax instruments in the Spanish economy. We have design a novel simulation strategy to compute the tax interaction effects from the existing taxes in the Spanish system. Following Goulder (1998) the strength of the pre-existing tax interaction effect is relevant for increasing the possibility of achieving the aforementioned second dividend.

Apart from tax instruments, there are some alternative policies for trying to achieve the goal of "decoupling", i.e. relaxing the interdependencies between economic activity and environmental degradation, namely, energy efficiency policies. According to the International Energy Agency (IEA), energy efficiency gains and energy savings should be able to contribute up to 43 percent in reducing current levels of energy use. However, among them, energy efficiency policies turn out to be the most effective policy tool. The reason behind this is that we consume energy services and not energy itself. Then it is always possible to do "the same with less". In doing so, we bring into play "ideas" in the form of technological enhancements. As pointed out by Simon (1981), technology helps societies to maintain their life standards and even improve them using less resources and/or implementing better allocations. Some words of wisdom by Keynes (1936) can also be invoked: "*even during financial crisis, resources and human ideas still are there*".

Energy efficiency policies are usually based upon technological change. These factor-augmenting or non-neutral technological improvements allow energy to become more productive in a higher proportion than the rest of used inputs. Therefore a lower amount of energy will be needed to produce the same amount of output. Differently to price policies, energy efficiency policies present many positive derived effects, namely: a) energy efficiency improvements increase productivity and consequently they boost economic growth, and b) energy efficiency gains favour countries' trade balance improving competitiveness levels and reducing energy imports. This explains why efficiency improvements in energy use have become one of the main concerns of the European Union Energy Policy[3]. As a consequence, many European governments have enacted especial plans and policies targeted to attain this goal[4]. However, and differently to the other alternative policies mentioned above, in this case substitution effects will work in the opposite direction: energy productivity gains push down energy effective prices increasing the attractiveness in the use of this input in the production process substituting other less pollutant inputs by energy. Additionally, if energy prices do not change, reductions in effective and/or actual prices of this input lead to output/competitiveness, composition and income effects. The sum of all these effects

[3] See "Commission Green Paper: A European Strategy for Sustainable, Competitive and Secure Energy". March, 2006.

[4] In the case of Spain through the "Plan de Acción 2005-2007" derived from Directive E4-2004-2012.

acts to offset the decreases in energy consumption that accompany pure efficiency effects. This implies that part or even all initial energy savings expected by the policy might be lost. It is therefore not certain that using energy more efficiently reduces the demand for it proportionally. The "Rebound-Effect" is a mean of quantifying this impact (Jevons, 1865; Khazzoom, 1980; Brookes, 1990; Saunders, 1992, 2000a, b; Schipper, 2000) also known as the "Khazzoom-Brokes" postulate. Therefore, despite boosting economic growth and favouring trade balance, if rebound effects are at work, energy efficiency policies might lose their effectiveness in reducing intermediate energy use and its derived emissions levels.

The question is then how to implement policy instruments to reach energy efficiency gains while avoiding or limiting the price mechanism that erodes potential energy savings. One of the core strategies proposed by rebound analysts has been the simultaneous combination of environmental taxes with energy efficiency gains (Greening *et al*, 2000; and Sorrell, 2007). Implementing these green taxes effectively compensate in the short-term the decline in the effective price of energy from efficiency improvements, hence restricting the presence and size of rebound effects. These price policies generate opposite behavioural responses to those that work against the preservation of potential energy savings. Additionally, a kind of extension of the "double-dividend" conceptualisation is also possible, though it has not been yet mentioned neither by specialists in this field nor by policy makers. A GTR with energy efficiency gains might reduce overall emissions levels (first dividend) while increasing the degree of efficiency in the economy (second dividend) and employment levels (third dividend) and the effectiveness of energy efficiency policies (fourth dividend). Evaluating this novel scenario whereby rebound effects might be mitigated constitute an additional contribution of our analysis.

This report is organized as follows. Section II deals with the economic efficiency components of GTRs and justifies the relevance of computing tax interaction effects for identifying how these policies should be designed to maximise the possibility of a second dividend. Section III presents our simulation results and Section IV concludes our analysis. A short description of the model being used is included in the Appendix.

II.THE ECONOMIC EFFICIENCY COMPONENTS OF GREEN TAX REFORMS: THE ROLE OF THE TAX INTERACTION EFFECT

The most important rationale for GTR is based not only on their ability to improve environmental quality, i.e. first dividend, but also on the possibility of reducing overall efficiency costs of the economy's tax system, i.e. second dividend. Whether or not the DDH is fulfilled is a very appealing issue among environmental protectionists. Following Goulder (1998), an specific policy is worthwhile to be applied if it generates a positive net benefit constituted as the difference between its associated gross benefits and gross costs. However, depending on the sign of the associated gross costs, this author distinguishes between two versions of the DDH, namely, the strong DDH (SDDH) and the weak DDH (WDDH). If the strong version of this hypothesis is fulfilled, gross costs are negative implying that even if the gross benefit are small, the tax reform improves overall economy welfare levels. Nevertheless, if the WDDH turns to be true, the size of the gross benefit is relevant since gross costs in this case are positive. Consequently, in evaluating or estimating the DDH what matters is the measure and size of the gross costs of GTR.

In order to understand the components and determinants of the first and second dividend, following Goulder (1998) and Bento and Jacobsen (2007), we use a two-good, one-factor general equilibrium framework. Therefore, an economy is assumed to produce an aggregate of clean commodities $Y = Y(L_Y)$ and an aggregate of dirty goods $Z = Z(L_Z)$. There is a representative consumer who owns an endowment of time, denoted by $\overline{T}$, that is split into hours of work, $L_Z + L_Y$, and hours of leisure l according to its preferences. Production and thus consumption of the dirty goods generate a derived supply of emissions that harm "environmental quality", Q, which in turn generates disutility to consumers. This representative consumer faces the following utility maximizing problem:

$$Max_{Y,Z,l}\Omega(Y,Z,l) + \Omega_E(Q(Z)) \qquad (1)$$

s.t. $P_Z Z + Y = (\omega - t_l)(L_Z, L_Y) + TR$

Where ω, t_l and TR refer respectively to the price of labour, the labour tax and the tax revenue that is the sum of labour and environmental taxes. This Tax Revenue is returned to consumers in the form of a lump-sum transfer. From (1) we can get the indirect utility function:

$$V(p_Z, \omega, t_E, t_l) + \Omega_E(Q(Z)) \tag{2}$$

Totally differentiating (2) with respect to a possible GTR, i.e. simultaneous changes in environmental tax, t_E and labour tax while keeping tax revenues constant we get:

$$\frac{dV}{\lambda dt_E} = \left(\frac{\Omega_E^{'}}{\lambda} - \frac{dp_Z}{dt_E}\right)\left(-\frac{dZ}{dt_E}\right) + t_l\left(\frac{\partial L}{\partial p_Z}\frac{dp_Z}{dt_E}\right) + t_l\left(\frac{\partial L}{\partial t_l}\frac{dt_l}{dt_E}\right) \tag{3}$$

Expression (3) above represents the overall efficiency impact of the GTR. The first component is the partial equilibrium or *Pigouvian gain effect* associated to the reduction in the consumption of the dirty good multiplied by the distance between marginal social cost and marginal social benefit. The second component is the *tax interaction effect* (Parry, 1995; Bovenberg and Goulder, 1996, 1997) that measures the welfare loss from increasing the final price of the dirty good relative to the price of leisure. This is because, due to market interactions, environmental taxes constitute implicit taxes on other factors of production. This impact of the GTR magnifies the before-GTR market distortions. The last component is the *revenue-recycling effect* and refers to the welfare gain when reducing pre-existing tax distortions, in this case, generated by the existing labour tax. Differently to the Pigouvian effect, the second and the third component are indirect or secondary effects since they stem from the existing market interdependencies in the economy.

The *tax interaction effect* and the *revenue-recycling effect* are key measures for determining the sign and size of the gross costs associated to the GTR and thus for the existence of the DDH. According to previous literature, the revenue-recycling effect is usually negative since the tax swap might not alleviate existing distortions. However, the tax interaction effect can present both signs, either positive or negative. If the former effect is small and the latter effect is positive and strong, the DDH might not arise. Therefore, the existence of the DDH highly depends on the size of pre-existing distortions closely linked to the tax interaction effect, the strength and nature of market interdependencies, i.e. the degree of “flexibility” in agents choice and sectors technology.

For the specific case of GTR, CGE models constitute perhaps one of the most appropriate tools since they allow us to measure the secondary effects of policies of this type i.e. *the tax interaction effect and the revenue recycling effect*. This is the reason why many analysts have used this methodology to evaluate the impacts of potential GTRs and thus, the possibility of the DDH (Gloswsrod et al, 1992; Pireddu and Dufournand, 1996, Wender, 2001; Yang, 2001, Babiker et al, 2003). For the case of the Spanish economy it is worthwhile to mention the analyses of Labandeira et al.(2004) and Manresa and Sancho (2005). However, though the nature of these models allows taking into account the two aforementioned effects conditioned by pre-existing distortions for the possible economy-wide outcomes of GTRs, to the best of our knowledge, no previous analysis has used the CGE approach to compute pre-existing distortions to identify the most appropriate tax swap when considering an increase in environmental taxes. Identifying this tax might help to increase the possibility of a positive second dividend. The novel simulation strategy that we have followed to isolate and compute the tax interaction effect that is part of the pre-existing tax distortions is explained in detail along the next sub-section.

III. RESULTS

III. (i).Efficiency of the Spanish Tax System: Isolating the Tax Interaction Effect.

As might be asserted from the discussion of the double-dividend hypothesis (section II) introducing green tax reforms implies two types of costs in terms of efficiency, i.e. the tax interaction effect and the revenue-recycling effect. Many analysts have considered that the weak version of the double dividend hypothesis is possible as far as the compensating reduction in the pre-existing tax when increasing green taxes is sufficiently high. The first question we want to address in this section is which tax figure in the current Spanish tax system is the most costly in efficiency terms. This question is relevant to approximate in a disaggregated way the aforementioned interaction tax effects and thus for a more efficient application of GTRs in the Spanish context. The results might help also to understand under which scenarios the DDH, be it under its weak or strong versions, might not be reached in our economy due to its structure.

The first analysts to use CGE models to analyse the marginal efficiency costs generated by the tax system were Ballard et al. (1985). Following these authors, González-Páramo y Sanz (2001), Alonso and Manzano (2003), Sancho (2004) have used a similar approach to explore this question for the case of the Spanish economy, i.e. evaluating marginal changes in taxes to compute the potential efficiency losses generated by each tax instrument. However, to our knowledge, all previous analysis did not consider the possibility of using the CGE approach to disaggregate the two dimensions of these efficiency losses, namely, the tax specific effect only due to each tax instrument and the tax interaction effect, i.e. when this tax instrument interact with other taxes. The former refers to that excess burden that is exclusively generated by the tax while the latter occurs when a specific tax interacts with the other existing taxes in the system, exacerbating the overall welfare losses. In isolating these two dimensions of all tax instruments in the Spanish economy, i.e. social security contributions paid by employer (Tl_F), social security contributions paid by employees (Tl_H),the value-added tax (T_{IVA}), taxes on exports (T_X), indirect taxes on domestic production (T_D), ad-quantum taxes on intermediate energy consumption (T_E) and ad-quantum taxes on CO_2 emissions levels[5] (T_{Em}) we have followed a simulation strategy that conform three steps:

Step one: We evaluate a scenario whereby overall taxes are set to zero with the exception of a specific tax instrument.

Step two: We benchmark a scenario under which the selected non-zero tax changes by 5%. This allows the identification and isolation of the welfare loss which is specifically due to this tax. Under this scenario the tax interaction effect is zero.

[5] We have not computed the tax interaction effect for personal income tax, though it is considered to isolate this effect for the other existing taxes in the Spanish economy.

Step three: we sequentially introduced benchmark tax rates to the second step simulation. The Tax Interaction Effect between the non-zero tax and each of the existing taxes in the economic system can be evaluated and thus isolated. In doing so we compute the difference between welfare losses obtained under the second step and those obtained by the third step simulation. This is done for the three most distorting taxes identified under the Second step.

According to the analysis of Goodstein (2002), labour supply conditions to determine the size of the aforementioned tax interaction effects and, consequently, pre-existing tax distortions that remarkably influence the likely of the DDH. For this reason, these three steps have been applied for two possible labour market scenarios: the existence of equilibrium voluntary and involuntary unemployment.

The key measure most commonly used by previous studies in order to compare the outcomes of various tax policies scenarios, such as those described above, is the excess burden, also known as deadweight loss. The excess burden is defined as the amount of economic welfare eroded when governments "subtract" private resources to finance public activities. One of the main objectives of a desirable tax system is to minimize this deadweight loss due to the economic distortions introduced by taxes. Since the analysis of Harberger (1964) and later on the studies of Shoven and Walley (1984), most analyses using the CGE approach have approximate the excess burden using either the compensated or the equivalent variation. However, apart of the problems of aggregation of preferences, these measures are sensitive to the initial assumptions imposed about the idiosyncratic characteristics of households.

Other analysts have preferred to use as tax policy selection criteria the costs of public funds (CPF), a concept that is closely related to the excess burden. This measure is usually expressed as an average elasticity of real GDP to real government resources once changes in average tax rates are evaluated. Other authors have instead used the ratio of households' welfare change to real government expenditure (Sancho, 2004). This is the Pigouvian concept of the CPF (Pigou, 1947). This alternative measure of the efficiency of the tax system, although also conditional to the agents' behavioural assumptions of the CGE model, is used as a complementary measure along with the money metric utility function using as indicator the EV as welfare measures of the impact of tax instruments under Step Two of the aforementioned simulation strategy.

Table 1: Results of Step Two. Specific Efficiency Losses of Taxes in the Spanish Economy. EV expressed in millions of euros 2004.

	Voluntary Unemployment.			Involuntary Unemployment		
	EV	**% EV on household income under Step 1**	**CPF**	**EV**	**% EV on household income under Step 1**	**CPF**
Tl_F	-3980.08	0.62%	5.81%	-3510.00	0.56%	0.79%
Tl_H	-1713.12	0.24 %	0.013%	-1829.11	0.27 %	0.70%
T_{IVA}	-2081.98	0.28%	1.22%	-2847.84	0.39%	67 %
T_X	-8.22	0.00%	1.20%	-11.42	0.02%	97.3%
T_D	-2169.30	0.29%	1.77%	-2940.14	0.29%	98%
T_E	-436.00	0.05%	3.50%	-633.20	0.08%	100%
T_{Em}	-0.0000	0.00%	0.85%	14.150	0.00%	52.30%

The results obtained under the Step two and considering the two labour market scenarios are depicted in Table 1. As can be asserted from this table, the tax with the highest implicit economic distortions corresponds to the social contributions paid by employers (Tl_F). In the same terms, this tax is followed by the indirect taxes on domestic production (T_D) and the value-added tax (T_{IVA}). The same order remains in terms of the EV under the two labour market scenarios. Nevertheless, when unemployment is involuntary being modelled by a wage curve, welfare losses are stronger than when employment is voluntary. This outcome stems from the fact that when unemployment is involuntary changes in real wages affect more directly to employment decisions and thus, to household income. Our results do not strongly differ to those obtained by Sancho (2004) with the exception of the social contributions paid by employees, i.e. Tl_H. According to our results, the "specific" efficiency losses of this tax instrument have turn to be much lower than those found by Sancho (2004). There are two reasons that might help to justify these results. Firstly the benchmark data used by this author corresponds to the base year 1990 while our data refers to the base year 2004. Secondly, in our model the structure of production is more complex since it includes a wider range of price interactions.

We can see that energy taxes are remarkable distorting. This is not the case, however, for emissions taxes. A possible explanation lies in the fact that energy taxes act as additional indirect taxes on domestic production and therefore we can expect, in terms of efficiency losses, similar effects to those attributed to other indirect production taxes.

Table 2a: Efficiency Losses of Taxes in the Spanish Economy. The Interaction Tax Effects. Scenario: Voluntary Unemployment. EV expressed in millions of euros 2004.

	$\frac{\Delta Tl_F}{Tl_F}=5\%$		$\frac{\Delta T_{IVA}}{T_{IVA}}=5\%$		$\frac{\Delta T_D}{Tl_D}=5\%$	
	EV	**Interaction Tax Effect**	**EV**	**Interaction Tax Effect**	**EV**	**Interaction Tax Effect**
Tl_F			-102713.94	-100631.96	-102806.82	-100637.52
Tl_H	-29675.54....	-26165.54	-36282.23	-34200.25	-36364.77	-34195.47
T_{IVA}	-40107.91	-36597.91	..	..	-43470.79	-41301.49
T_X	-4127.81	-617.81	-2255.51	-173.53	-2308.86	-139.56
T_D	-44125.08	-40615.08	-48087.98	-46006.00	..	..
T_E	-12588.75	-9078.75	-11544.81	-9462.83	-10246.67	-8077.37
T_{Em}	-4145.01	635.01	-2264.02	-182.04	-2338.85	-169.55

Table 2b: Efficiency Losses of Taxes in the Spanish Economy. The Interaction Tax Effects. Involuntary Unemployment. EV expressed in millions of euros 2004.

	$\frac{\Delta Tl_F}{Tl_F}=5\%$		$\frac{\Delta T_{IVA}}{T_{IVA}}=5\%$		$\frac{\Delta T_D}{Tl_D}=5\%$	
	Total EV	**Interaction Tax Effect**	**Total EV**	**Interaction Tax Effect**	**Total EV**	**Interaction Tax Effect**
Tl_F			-98116.8	-95269.0	-98429.3	-95489.1
Tl_H	-311948	-27684.8	-38351.7	-35503.9	-38296.3	-35356.1
T_{IVA}	-53197	-49687	..		-57961.7	-55021.6
T_X	-3719.95	-209.95	-3087.55	-239.71	-3132.02	-191.88
T_D	-58343.4	-54833.4	-63803.5	-60955.6	..	..
T_E	-17112.6	-13602.6	-16140.2	-13292.4	-14237.8	-11297.6
T_{Em}	-3763.87	-253.87	-3105.5	-257.66	-3177.64	-237.5

In following Step three of our simulation strategy, we have obtained the results shown in Tables 2 (a)–(b). As mentioned above, the idea behind this simulation was to isolate the tax interaction effect. From these findings, two main conclusions might be drawn. Firstly, those taxes that appeared to be the most distorting in isolation, when we consider their interaction with other high-distorting taxes, we can see that the strength of the tax interaction effect leads to a remarkable multiplicative impact on welfare levels. This is the case when changes in indirect taxes, such as those charged on domestic production and taxes on value added, occur in the presence of the social contributions paid by employers. This is not the case of emissions taxes that slightly affect overall welfare levels with a modest contribution to the tax interaction effect.

The other result we would like to point out is that under the scenario of involuntary unemployment, the tax interaction effect of indirect taxes that stems from the social contributions paid by employers, though still remarkably strong, appears to be much lower than the other alternative labour market scenario. This reinforces the idea that the labour market scenario is a key issue in determining the impacts of GTRs, especially in the case of the second dividend since pre-existing tax distortions turn out to be also sensitive to the way labour supply works.

All these results, together with our novel contribution for disaggregating tax interaction effects from overall tax welfare losses, help to identify which tax among the wide range of tax instruments in the Spanish economy should be used to compensate possible increases in green taxes, either emissions or energy taxes. According to our results, though social contributions paid by employers are good candidates for the GTRs, we explore in the next section the possibility of driving these reforms through indirect taxes and a "hybrid tax reform policy" too, i.e. compensating increases in green taxes with decreases in labour taxes while avoiding the erosion of actual energy savings when rebound effects are at work.

III.(ii). Green Tax Reforms Possibilities in the Spanish Economy

To explore the potential for a DD in the Spanish economy under GTRs, and similarly to previous studies on this issue, we have evaluated changes in environmental taxes—both emissions and energy taxes—that endogenously lead to a reduction in pre-existing tax rates in such a way that tax revenues remain unchanged. For a government revenue neutral effect, the evaluated increases in environmental taxes are compensated through out those taxes that under sub-section III.(i) we have identified as the most distorting tax instruments in the Spanish system, namely, social security contributions and indirect taxes on domestic production. This is because, as indicated in the introduction, one of the main reasons that justify the application of GTRs is not only reducing overall emissions levels (*first dividend*) but also to improve the degree of efficiency of the overall tax system (*second dividend*).

There is also the possibility of a *third dividend* that has to do with the impact that GTRs might potentially have on labour supply, i.e. the effect on real wages and unemployment levels. This *third dividend* is a derived impact from the tax interaction effect that usually affects negatively employment levels (Goodstein, 2002). Whether this third dividend is positive or negative highly depends on the existing interactions between labour supply and final prices. These third dividend effects of GTRs have been the focus of many researchers using the CGE approach (Schneider, 1997; Koskela and Schöb, 1999, Patuelli et al. 2005). Taking into account all these findings, we have including the possibility of two labour market scenarios. Additionally, reflecting in our model these two labour market scenarios helps to understand the differences in the conclusions drawn by previous empirical analysis carried out for the Spanish economy, i.e. Labandeira et al. (2004), and Manresa and Sancho (2005)

Furthermore, since our intention in this section is to extent and complement previous analysis of GTRs in the context of the Spanish economy, both energy and emissions taxes are modelled in a slightly different way in the sense that these two environmental taxes are initially disaggregated from the benchmark data and that they are considered to be *ad-quantum* taxes. In our view, this makes our simulations closer to the actual tax code and our results more realistic than those obtained under previous analysis.

Table 3a. GTRs with endogenous changes in social security contributions paid by employers. Voluntary unemployment

	$\frac{\Delta T_E}{Tl_E}=8\%$ and $\frac{\Delta T_{Em}}{Tl_{Em}}=8\%$		$\frac{\Delta T_E}{Tl_E}=8\%$ and $\frac{\Delta T_{Em}}{Tl_{Em}}=0\%$		$\frac{\Delta T_E}{Tl_E}=0\%$ and $\frac{\Delta T_{Em}}{Tl_{Em}}=8\%$	
	$\psi=0.8<1$	$\psi=1.2>1$	$\psi=0.8<1$	$\psi=1.2>1$	$\psi=0.8<1$	$\psi=1.2>1$
Δu	-0.03%	-0.05%	-0.03%	-0.05%	-0.01%	-0.01%
EV	+195	+248	+186	+237	10	11
ΔEm	-0.93%	-0.92%	-0.93%	-0.92%	-0.006%	-0.005%
ΔGDP	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
ΔTl_F	-0.42%	-0.45%	-0.41%	-0.44%	-0.01%	-0.009
Effective ΔT_{Em}	6.85%	6.86%	-1.38%	-1.13%	8%	8%

Δu % changes in unemployment , EV equivalent variations in millions of 2004 euros, ΔEm % changes in CO_2 ΔGDP % change in real GDP

Table 3b. GTRs with endogenous changes in social security contributions paid by employers. Involuntary unemployment

	$\frac{\Delta T_E}{Tl_E}=8\%$ and $\frac{\Delta T_{Em}}{Tl_{Em}}=8\%$		$\frac{\Delta T_E}{Tl_E}=8\%$ and $\frac{\Delta T_{Em}}{Tl_{Em}}=0\%$		$\frac{\Delta T_E}{Tl_E}=0\%$ and $\frac{\Delta T_{Em}}{Tl_{Em}}=8\%$	
	$\beta=-0.13$	$\Delta\beta=5\%$	$\beta=-0.13$	$\Delta\beta=5\%$	$\beta=-0.13$	$\Delta\beta=5\%$
Δu	-0.18%	-0.15%	-0.15%	-0.17%	-0.01%	-0.01%
EV	+813	+754	+724	+781	34	32
ΔEm	-0.84%	-0.85%	-0.85%	-0.84%	-0.002%	-0.002%
ΔGDP	0.10%	0.09%	0.09%	0.10%	0.00%	0.00%
ΔTl_F	-0.68%	-0.66%	-0.64%	-0.66%	-0.02%	-0.01
Effective ΔT_{Em}	6.9%	6.93%	-1.06%	-1.05%	8%	8%

Δu % changes in unemployment , EV equivalent variations in millions of 2004 euros, ΔEm % changes in CO_2 ΔGDP % change in real GDP

Table 4a. GTRs with endogenous changes in indirect taxes on domestic production. Voluntary unemployment

	$\frac{\Delta T_E}{Tl_E}=8\%$ and $\frac{\Delta T_{Em}}{Tl_{Em}}=8\%$		$\frac{\Delta T_E}{Tl_E}=8\%$ and $\frac{\Delta T_{Em}}{Tl_{Em}}=0\%$		$\frac{\Delta T_E}{Tl_E}=0\%$ and $\frac{\Delta T_{Em}}{Tl_{Em}}=8\%$	
	$\psi=0.8<1$	$\psi=1.2>1$	$\psi=0.8<1$	$\psi=1.2>1$	$\psi=0.8<1$	$\psi=1.2>1$
Δu	-0.01%	-0.01%	-0.01%	-0.01%	-0.00%	-0.00%
EV	+66	+64	+67	+66	+2	+2
ΔEm	-0.93%	-0.93%	-0.92%	-0.92%	-0.006%	-0.006%
ΔGDP	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
ΔT_D	-2.42%	-2.48%	-2.35%	-2.37%	-0.07%	-0.07%
Effective ΔT_{Em}	6.88%	6.88%	-1.11%	-1.11%	8%	8%

Δu % changes in unemployment , EV equivalent variations in millions of 2004 euros, ΔEm % changes in CO_2 ΔGDP % change in real GDP

Table 4a. GTRs with endogenous changes in indirect taxes on domestic production. Involuntary unemployment

	$\frac{\Delta T_E}{Tl_E}=8\%$ and $\frac{\Delta T_{Em}}{Tl_{Em}}=8\%$		$\frac{\Delta T_E}{Tl_E}=8\%$ and $\frac{\Delta T_{Em}}{Tl_{Em}}=0\%$		$\frac{\Delta T_E}{Tl_E}=0\%$ and $\frac{\Delta T_{Em}}{Tl_{Em}}=8\%$	
	$\beta=-0.13$	$\Delta\beta=5\%$	$\beta=-0.13$	$\Delta\beta=5\%$	$\beta=-0.13$	$\Delta\beta=5\%$
Δu	0.05	0.05	0.01	0.01	-0.01	-0.01
EV	88	89	90	91	30	30
ΔEm	-0.93%	-0.93%	-0.93%	-0.93%	-0.056%	-0.056%
ΔGDP	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
ΔT_D	-2.34%	-2.34%	-2.27%	-2.26%	-0.07%	-0.07%
Effective ΔT_{Em}	6.7%	6.8%	-1.12	-1.12	7.9%	7.9%

Δu % changes in unemployment , EV equivalent variations in millions of 2004 euros, ΔEm % changes in CO_2 ΔGDP % change in real GDP

Tables 3a-3b depict the likely impacts when adopting GTRs in the Spanish context that imply an increase in environmental taxes, i.e. energy taxes and emissions taxes, while reducing social security contributions paid by employers. Tables 4a-4b show the possible outcomes when indirect taxes on domestic production are chosen instead of the labour tax. Three possible GTRs scenarios have been considered under the two labour market structures considered in our study, namely, homogenous simultaneous changes in both energy taxes and emissions taxes, changes in energy taxes alone, and variations in emissions taxes while keeping energy taxes at benchmark levels. For each GTRs scenarios, labour market parameters have been also changed reflecting initial benchmark values and more flexible situations where labour supply is more sensitive to changes in real wages, i.e. $\psi = 1.2 > 1$ and $\Delta\beta = 5\%$ where ψ and β refer to those parameters that determine respectively the elasticity of substitution between consumption and leisure under the voluntary unemployment scenario and and the elasticity of unemployment with respect to real wages under the involuntary unemployment scenario.

As can be asserted from the results in Tables 3a-3b and Tables 4a-4b, impacts on welfare levels (second dividend) and in unemployment levels (third dividend) that stem from the simulated GTRs differ remarkably between the two alternative labour market scenarios. Although the direction of change is the same, the effects on welfare and employment levels turn out to be stronger under the involuntary employment scenario than under the alternative labour market structure. Consequently, these results reinforce the statement that the way labour supply works within the structure of an economy is a key issue in determining the possibility of the DDH from GTRs. As indicated in sub-section III.(i) the role of the labour supply is relevant since it determines the size of pre-existing distortions. The higher the pre-existing distortions, the stronger the positive effects derived from GTRs. This also helps to understand why previous analyses on GTRs for the Spanish economy differ in their conclusions. The analysis of Manresa and Sancho (2005) explores the possibility of the existence of the DDH in an equilibrium with involuntary unemployment that takes into account the role that labour market rigidities might exert over the effects of the GTR in the Spanish context. The main conclusion drawn in this study, and also found in our results, is that less rigidity in the labour market would favour the possibility of an employment second dividend. The approach of Labandeira et al. (2004), however, includes voluntary unemployment and goes one step further implementing substitution between energy commodities and value-added in the production function, a key aspect for evaluating the DDH (Bovenberg and Goulder, 2002). Consequently, since when voluntary unemployment is present the effects on welfare and unemployment levels that stem from GTRs are low, their findings were quite different to those obtained by Manresa and Sancho (2004) concluding that the effects of a GTR are almost nil in terms of welfare and employment. Labandeira et al. (2004) mention in their analysis that one reason that could explain the wedge between their results and those obtained by Manresa and Sancho (2004) is the way the production structure is modelled in the CGE approach, i.e. substitution between energy commodities and value-added is implemented in their model. From our findings, however, it appears that the production structure is not a key issue for the evaluation of the effects of GTRs, but rather a "secondary" determinant. The size of the effects seems to follow essentially from the adopted structures of the labour market. We have considered two alternative labour market scenarios under the same substitution possibilities between energy and value-added (See Appendix).

Once we have justified why there have been, in the literature, conflicting results about the possible effects of the GTRs in the Spanish context, we now move to explain our novel findings. Firstly, the results obtained in this section reinforce the statement that, prior to carrying out GTRs, tax interaction effects for each tax instrument in the economy should be assessed and analysed. As indicated in sub-section III.I computing an approximate measure of the tax interaction effect helps to identify which tax could potentially maximise the possibility of second and third dividends. According to our results in sub-section III.I, the social security contributions paid by employers can be considered as the most distorting tax in the Spanish economy followed by indirect taxes on domestic production. Consequently, the results in terms of the second and third dividend, when GTRs are applied using this labour tax, are on average much higher than when indirect taxes on domestic production are used with the same purpose. Nevertheless, the effect in terms of the first dividend, i.e the decline in overall CO_2 emissions levels, appears to be quite similar. Secondly, combining reductions in social contributions paid by employers with joint increments in both energy and emissions taxes appears to be more effective than when only one of these two environmental taxes is changed. The reason behind this result is the implicit effect that higher energy taxes have over effective emissions taxes. Higher energy taxes changes the optimal technological combination technology and thus the technology in terms of emissions is also altered. Consequently, as indicated along the last row of Tables 3a-3b and 4a-4b carrying out GTRs with energy taxes alone might decrease the average effective "price" of emissions. Thirdly, reflecting realistic *ad-quantum* environmental taxes is relevant for the size of the likely impacts of GTRs. Simulating these taxes as *ad-valorem* taxes might exacerbate overall results and, specially, the evaluated change in the labour tax and thus on welfare levels as in the analysis of Manresa and Sancho (2004).

III.(iv) Policy Scenarios for the Mitigation of Rebound impacts: a possible complementary fourth dividend.

We devote this last sub-section to evaluate the possibility of a fourth dividend from GTRs: the mitigation of the rebound effect that negatively affects the effectiveness of energy efficiency policies. Rebound effects refer to the relative distance between potential and actual energy savings, *PES* and *AES* thereafter:

$$R = \left(1 - \frac{dE / E}{d\tau / \tau}\right) = \left(1 - \frac{AES}{PES}\right) \tag{4}$$

Consequently, rebound measures quantified the proportion of *PES* that are eroded once price mechanisms are at work leading to the *AES*. As mentioned in the introduction, some researchers have considered that the most effective policy instruments to mitigate rebound impacts are energy taxes. A simultaneous combination of an increase in energy taxes along with energy efficiency gains might counteract the price mechanisms that lead to rebound impacts and negatively affect the effectiveness of energy efficiency policies.

The idea of this section is to show that there are complementarities between GTRs and energy efficiency policies, i.e. one policy might reinforce the positive effects of the other if they are simultaneously implemented. In doing so, we have first evaluated the potential economy-wide rebound effects when energy efficiency increased by 5%. The energy efficient shock introduced in the CGE approach to evaluate actual energy savings under general equilibrium conditions (AES) is carried out by increasing the benchmark productivity of the energy composite. i.e. benchmark effective energy composite by 5 percentage points in the production structure presented in expression A.2 in the Appendix:

$$\frac{d\left(\tau \cdot E\right)}{\bar{\tau} \cdot \bar{E}} = \frac{d\tau}{\bar{\tau}} = 5\% \qquad \text{with} \quad \frac{dE}{\bar{E}} = 0 \tag{5}$$

This energy efficiency shock is homogenous for all of the 16 production sectors that we consider (see table AP1 in the Annex). This is a one-off exogenous (and costless[6]) energy augmenting technological progress (i.e. increasing units of output produced per unit of energy input). Note that in this analysis we apply the efficiency shock only to the use of domestically supplied energy and not on imported energy inputs. The *PES* are computed following the suggestions of Guerra and Sancho (2010) for an unbiased indicator. Secondly, these energy efficiency gains are simultaneously evaluated with changes in environmental taxes, i.e. energy and emissions taxes. Lastly a GTRs scenario is considered with social security contribution paid by employers. In all these simulations, we have considered that unemployment is involuntary.

Table 5. Increases in Environmental Taxes and Exogenous Energy Efficiency Gains. Involuntary unemployment

	$\frac{\Delta T_E}{Tl_E}=8\%$ *and* $\frac{\Delta T_{Em}}{Tl_{Em}}=8\%$	$\frac{\Delta T_E}{Tl_E}=15\%$ *and* $\frac{\Delta T_{Em}}{Tl_{Em}}=15\%$
Δu	-0.38%	-0.37%
EV	3794	3342
ΔEm	-0.72%	-1.57%
ΔGDP	0.79%	0.75%
R	80.50%	73.57%

Δu % changes in unemployment , EV equivalent variations in millions of 2004 euros, ΔEm % changes in CO_2, ΔGDP % change in real GDP, R the economy-wide rebound effect

The simulated costless exogenous improvements in energy efficiency indicate that the potential economy-wide rebound effect for the Spanish economy amounts to 90.81 %. Therefore, from the 5 percent increase in energy efficiency levels of only 0.5% are effectively reached due to the decline in the effective price of energy. According to the results presented in Table 5, when these energy efficiency improvements are simultaneously evaluated with increases in environmental taxes, our results indicate that part of the potential energy savings might be preserved leading to an overall decline in CO_2 emissions levels and a remarkable increase in welfare. Nevertheless rebound impacts are mitigated at the costs of lower impacts on growth and employment levels when energy efficiency gains alone take place.

[6] Incorporating cost considerations when introducing an energy efficiency improvement will affect the nature and size of rebound effects (see Allan et al, 2007; Sorrel, 2007), as will the precise nature of its introduction. Here, in the first instance, the analysis is simplified by focussing on an exogenous and costless increase in energy efficiency. This is an important step as it allows us to consider the main basic drivers of the rebound effect (i.e. the general equilibrium responses to reductions in effective, and actual, energy prices) in isolation.

Table 6. GTRs with endogenous changes in social security contributions paid by employers and Exogenous Energy Efficiency Gains. Involuntary unemployment

	$\frac{\Delta T_E}{Tl_E} = 8\%$ *and* $\frac{\Delta T_{Em}}{Tl_{Em}} = 8\%$		$\frac{\Delta T_E}{Tl_E} = 15\%$ *and* $\frac{\Delta T_{Em}}{Tl_{Em}} = 15\%$	
	$\beta = -0.13$	$\Delta\beta = 5\%$	$\beta = -0.13$	$\Delta\beta = 5\%$
Δu	-0.82%	-1.10%	-0.98%	-1.17%
EV	6679	6534	7233	6927
ΔEm	-0.44%	-0.47%	-1.20%	-1.24%
$\Delta PIBreal$	1.14%	1.12%	1.22%	1.17%
ΔTl_F	-2.51%	-1.72%	-2.62%	-1.81%
R	84.40%	84.30%	78.64%	78.13%

The simulated results when GTRs take place together with energy efficiency gains are depicted in Table 6 above. Comparing these findings with those presented in Table 5 and Table 4a, the effects on both emissions levels (first dividend), welfare (second dividend) and employment (third dividend) are stronger than when energy efficiency improvements do not occur. This is because the presence of energy efficiency gains boosts economic growth increasing the possibility of reaching the DDH from GTRs. However, the mitigation of the economy-wide rebound effect is much moderate than when GTRs are not applied. Differently to the GTRs scenario alone, under this hybrid scenario, increasing the flexibility of the labour market disfavours the second and third dividend from the GTRs than a more rigid situation. Nevertheless, this flexibility helps to mitigate to a larger extent the rebound impact and thus the emissions levels, i.e. first dividend than under the benchmark situation.

IV. Conclusions

This analysis provides some empirical insights and evidence about the economy-wide impacts of GTRs as well as of “hybrid” policies that combine them with energy efficiency policies. The complementarities of GTRs and energy efficiency policies allow to reinforce the likelihood of the first dividend, the second dividend and the third dividend, i.e. the employment dividend, while mitigating the economy-wide rebound effects from energy efficiency policies—*the fourth dividend*. This is done in the Spanish context using the model structure described in Annex A. Thus we evaluate the possible welfare and macroeconomic economy-wide impacts of these possible scenarios.

Additionally, the target of this study was to extend and complement previous analyses on this issue for the specific case of Spain. In doing so, we have first implemented a novel simulation strategy that makes possible to evaluate both tax distortions specific to each tax figure in the Spanish economy and its derived tax interaction effect. The interest in computing this tax interaction effect stems from the fact that it constitutes a key issue in determining the likelihood of the DDH and thus the welfare and macroeconomic impacts of GTRs. According to our results, the social security contributions paid by employers turn out to be the most distorting tax in the Spanish tax system. For this reason, increases in environmental taxes, energy and emissions taxes, should be combined with government revenue neutral cuts in these taxes. Secondly, and differently to previous analyses, energy and environmental taxes are calibrated from real data in our approach. Our findings indicate that a more effective GTR should combine simultaneous increases in these taxes because of the implicit interdependencies between them. Thirdly, since in our analysis we have considered the two labour market scenarios, i.e. voluntary and involuntary unemployment, taking into account by previous similar approaches on this issue, this has helped to understand the discrepancies in the conclusions drawn by them. Comparing the outcomes obtained under two alternative labour market scenarios indicates that if voluntary unemployment does not exist, the possibility of the DDH might be downward biased since the impacts on welfare are remarkably lower than those obtained under the existence of involuntary unemployment. The contrary would occur if involuntary unemployment were not present in the Spanish economy. Finally, the last conclusion of our analysis is that at present environmental taxes in the Spanish economy are quite low, i.e. they represent 4 percent over GDP. In our findings, to carry out GTRs that would seek to reach an annual 2 percent decline in emissions levels alone would have modest effects on welfare and unemployment levels and would imply a considerably increase in environmental taxes, more than 20 percent. This completely coincides with previous research for the Spanish economy.

Bibliography:

Allan, G., Hanley N., McGregor, P.G., Swales, K., Turner, K., 2007. The macroeconomic rebound effect and the UK economy. Final report to the Department Of Environment Food and Rural.

Alonso, J. and Manzano, B. 2003, "Análisis dinámico del coste de bienestar del sistema impositivo español. Una aproximación cuantitativa", Hacienda Pública Española. 167, 9-31.

Armington, P., 1969. A theory of demand for products distinguished by place of production. IMF Staff Papers.16, 157-178.

Babiker, M.H., Metcalf, G.E. and Reilly, J. 2003. Tax Distortions and Global Climate Policy. Journal of Environmental Economics and Management.46, 269-287.

Ballard, C., Shoven, J. and Whalley, J. 1985. General Equilibrium Computations of the Marginal Welfare Cost of Taxation. American Economic Review. 75, 128-138.

Ballard, Charles L. 1999. How Many Hours Are in a Simulated Day? The Effects of Time Endowment on the Results of Tax-Policy Simulation Models. Working Paper. East Lansing, Michigan: Department of Economics, Michigan State University.

Blanchflower, D.G., Oswald, A.J., 1990. The wage curve. Scandinavian Journal of Economics 92, 214–235.

Blanchflower, D.G., Oswald, A.J., 1994. The Wage Curve. MIT Press, Cambridge, MA.

Böhringer, C., Ferris, M., Rutherford, T., 1997. Alternative CO2 Abatement Strategies for the European Union, in Proost, S. and Brader, J. (eds) Climate Change, Transport and Environmental Policy. Edward Edgar, Cheltenham.

Bovenberg, L., Goulder, L.H. 1996. Optimal Environmental Taxation in the Presence of other Taxes: General Equilibrium Analysis. American Economic Review. 4, 985-100.

Bovenberg, L. Goulder, J.H. 1997. Cost of Environmentally Motivated Taxes in the Presence of other Taxes: General Equilibrium Analysis. National Tax Journal. 50, 59-87.

Brookes, L. 1990. The Greenhouse Effect, the Fallacies in the Energy Efficiency Solution. Energy Policy, 18, 199-201.

Frisch, R., 1959. A Complete Scheme For Computing All Direct And Cross Demand Elasticities in a Model With Many Sectors. Econometrica 27, pp. 177-196

Glowsrod, S., Vennemo, H. Johnsen, T. 1992. Stabilization of emissions of CO_2: a Computational General Equilibrium Assessment. Scadinavian Journal of Economics. 94, 53-69.

González-Páramo, J. M. and J. F. Sanz .2001. ¿Quiénes se beneficiaron de la reforma del IRPF en 1999?: Una evaluación desagregada de sus efectos sobre la oferta de trabajo, el bienestar y el coste marginal de los fondos públicos", mimeo, Fundación BBVA.

Goodstein, E. 2002. Labour Supply and the Double Dividend. Ecological Economics.42, 101-106.

Goulder, L.H. 1998. Environmental Policy Making in a Second-Best Setting. Journal of Applied Economics, 1, 279-328.

Guerra, A.I., Sancho, F. 2010. Rethinking Economy-Wide Rebound Measures: An Unbiased Proposal. Energy Policy. Forthcoming.

Greening, L.A., Greene, D.L., Difiglio, C., 2000. Energy efficiency and consumption – the rebound effect – a survey. Energy Policy. 28, 389–401.

Harberger, A. 1964. Taxation, Resource Allocation and Welfare. In the Role of Direct and Indirect Taxes in the Federal Revenue System. Princeton University Press for NBER and the Brookings Institution.

Hertel, T. W. (ed.), 1997. Global Trade Analysis. Modeling and Aplications. Cambridge University Press, Cambridge.

Jevons, W.S. 1865. The coal question. Macmillan, London. Economic growth and income inequality, 1955. American Economic Review. 45, 1–28.

Khazooms, J.D, 1980. Economic Implications of Mandated Efficiency Standards for Household Appliances. The Energy Journal, 4, 21-40

Koskela, E. and R. Schöb .1999. Alleviating Unemployment: The Case for Green Tax Reforms. European Economic Review. 43,1723-1746.

Labandeira, X. Rodríguez, M. 2004. The effects of Sudden CO_2 Reduction in Spain. Documento de Traballo 0408. Departamento de Economía Aplicada. Universidade de Vigo.

Lee, D.R. and Misiolek, W.S. 1986. Substituting Pollution Taxation for General Taxation: Some Implications for Efficiency in Pollution Taxation. Journal of Environmental Economics and Management.13, 338-347.

Lluch, C., Powell, A., Williams, R.A., 1977. Patterns in household demand and savings. Oxford University Press, Oxford.

Manresa, A. and Sancho, F. 2005. Implementing a double dividend: Recycling ecotaxes toward lower labor taxes. Energy Policy. 33, 1577-1585.

Németh,G., Szabó, L., Ciscar, J.C., 2008. Estimation of Armington Elasticities in an Energy CGE model for Europe. Working paper of the Institutes of Prospective Technological Studies, Seville (Spain).

Parry, I. 1995. Pollution Taxes and Revenue Recycling. Journal of Environmental Economics and Management. 29, 64-77.

Patuelli, R., Nijkamp, P. and Pels, E. 2005. “Environmental Tax Reform and the Double Dividend: A Meta-Analytical Performance Analysis. Ecological Economics. 55, 564-583.

Pearce, D. 1991. The role of carbon Taxes in adjusting to global warming. Economic Journal. 101, 938-948.

Pigou, A.C. 1938. The Economics of Welfare. London: Weidenfeld and Nicolson.

Pigou, A. C. 1947. A Study in Public Finance. (3 rd. Edition). London: MacMillan.

Pisarides, Ch. 1998. The impact of Employment Tax Cuts on Unemployment and Wages: the Role of Unemployment benefits and Tax Structure. European Economic Review. 42, 155-183.

Pireddu, G., Dufournand, C.M. 1996. Econotaxes in an Italian CGE model: double dividend effects and the Distribution of Tax Burdens. In: Fossati, A. (Ed.). Economic Modelling under the Applied General Equilibrium Approach. Avebury Press, Great Britain

Poterba, J. 1993. Global Warming Policy, A Public Finance Perspective. The Journal of Economic Perspective. 7, 47-63.

Repetto, R, Dower, R.C., Jenkins, R. and Geoghegan, J. 1992. Green Fees: How a Tax Shift Can Work for the Environment and the Economy. World Resources Institute, November.

Terkla, D. 1984. The Efficiency Value of Effluent Tax Revenues. Journal of Environmental Economics and Management. 11,107-123.

Sancho, F. 2004. Una estimación del Coste Marginal de Bienestar del Sistema Impositivo en España. Hacienda Pública Española. 169, 117-132.

Sancho, F., 2009. Calibration of CES Functions for Real-World Multisectoral Modelling. Economic Systems Research. 21, 45-58

Sanromá, E., Ramos, R. 2003. Wage Curves in Spain. Evidence from the Family Budget Survey. Working Papers in Economics, Number 101. Espai de Recerca en Economia, Universitat de Barcelona.

Saunders, H.D., 1992. The Khazzoom–Brookes postulate and neoclassical growth. The Energy Journal 13, 131–148.

Saunders, H.D., 2000a. Does predicted rebound depend on distinguishing between energy and energy services?.Energy Policy.28, 497–500.

Saunders, H.D., 2000b. A view from the macro side: rebound, backfire, and Khazzoom–Brookes. Energy Policy .28, 439–449.

Schipper, L., 2000. Editorial. Energy Policy. 28, 6–7.

Schneider, K. (1997). Involuntary Unemployment and Environmental Policy: The DoubleDividend Hypothesis. Scandinavian Journal of Economics. 99 ,45-59.

Shoven, J., Whalley, J. 1984. Applied General Equilibrium Analysis of Taxation and Trade. Journal of Economic Literature. 22, 1007-1105.

Simon, J. 1981. The Ultimate Resource. Princeton University Press, Princeton.

Sorrell, S., 2007. The Rebound effect: an assessment of the evidence for economywide energy savings from improved energy efficiency. A report produced by the Sussex Energy Group for the Technology and Policy Assessment function of the UK Energy Research Centre.

Theil, H., Cheng, C.F., Seale, J.L. Jr. 1989. International Evidence on Consumption Patterns, Greenwich, CT: JAI Press, Inc.

Wender, R. 2001. An Applied General Equilibrium Model of Environmental Tax Refoms and Pension Policy. Journal of Policy Modelling. 23, 25-50.

Yang, J. 2001. Trade Liberalization and Pollution: A General Equilibrium Analysis of Carbon Dioxide Emissions in Taiwan. Economic Modelling.18, 435-454.

APPENDIX

A CGE MODEL FOR THE SPANISH ECONOMY

General description.

The model includes N=16 representative firms 4 types of inputs in production (capital. labour. energy and non-energy materials) a representative household. a government sector. an account for corporations an external sector and a capital (savings/investment) account. Agents behave rationally and are profit and utility maximisers. No agent has significant market power.

Each representative firm minimizes costs subject to a constant-returns-to-scale technological constraint. thus profits turn out to be zero. Markets are assumed to be competitive. Production is articulated using nested constant elasticity of substitution (CES) functions. In the first level gross output is obtained following an Armington (1969) assumption with imported products being imperfect substitutes for domestic production. In the next levels domestic output results from combining the 4 production inputs (capital. labour. energy and materials) using a succession of nested CES functions. Each representative firm produces a single good. These 16 sectors and goods are classified into 5 energy (sectors 2-3. 5-7) and 11 non-energy materials sectors (1. 4. 8-16). See sectoral details in Table AP1 below. This distinguishes two relevant production blocks in the economy: the energy block and the non-energy block. Both blocks make use of a multi-level and sectors' homogenous technology.

Consumption activities refer to those of a single representative household who demands commodities and savings under an income constraint. Income stems from selling labour and capital endowments plus net transfers from the government and corporations.

The government supplies a public consumption good, supports public investment and carries out income transfers to private sectors. These activities are financed through taxes and, if necessary, incurring in a public deficit. Taxes are of two general types: a direct income tax and a range of indirect taxes (production tax. value-added tax. payroll tax on labour. and tariffs).

Corporations act as an intermediary sector that makes transactions with the rest of the economic agents in terms of property income social contributions and transfers. The foreign sector plays a residual but nonetheless necessary role for closing the model. Imports are demanded by the domestic industries and they are used to yield along with domestic output, the total supply of goods. Part of this total supply is in turn demanded by the foreign sector as exports.

In equilibrium all markets clear with the possible exception of the labour market. Total supply of labour is fixed but is composed of two parts, one related to active labour being demanded by firms and another one that is idle and is interpreted as unemployment. The unemployment rate is made endogenous using a wage curve that relates unemployment to the level of the real wage rate in the economy. The closure rule guarantees that in equilibrium the aggregate equality between investment and savings holds.

The CGE model is implemented using a Social Accounting Matrix (SAM) of the Spanish economy for 2004. In the calibration all value flows are taken as benchmark quantities using the standard unit price normalization. Most model parameters can therefore be obtained from the reference SAM. To deal with the presence of taxes we use the methodology of Sancho (2009). Differently to previous analysis, we have calibrated both the initial energy and CO_2 emissions taxes that are introduced as *ad quantum* taxes. The exogenous elasticities have been decided upon literature search.

Total Production.

Gross output X_i for the set of tradable goods T is a CES composite between domestic output X_i^D and imports X_i^M :

$$X_i = \left[(a_i^D X_i^D)^{\rho_i} + (a_i^M X_i^M)^{\rho_i} \right]^{1/\rho_i} \qquad i \in T \subseteq N \quad N{=}16 \tag{A.1}$$

Thus there is imperfect substitution between domestic output and imports which is governed by an Armington elasticity $\sigma_i = 1/(1-\rho_i)$. We consider different Armington elasticities for the energy and non-energy block though homogenous within blocks. For non-tradable goods, total output coincides with domestic output.

Domestic Production: KLEM specification

Domestic production X_i^D is obtained using a CES *KLEM* (Capital *K*. Labour *L*. Energy *E*. and Materials *M*) nested production function:

$$\begin{aligned}
VA_i &= \left(\delta_i (A_i^K K_i)^{\rho_{K,L}} + (1-\delta_i)\left(A_i^L L_i \right)^{\rho_{K,L}} \right)^{1/\rho_{K,L}} \\
VAE_i &= \left(\beta_i (\tau E_i)^{\rho_{VA,E}} + (1-\beta_i) VA_i^{\rho_{VA,E}} \right)^{1/\rho_{VA,E}} \\
X_i^D &= \left(\alpha_i (A_i^M M_i)^{\rho_{M,VAE}} + (1-\alpha_i) VAE_i^{\rho_{M,VAE}} \right)^{1/\rho_{M,VAE}}
\end{aligned} \tag{A.2}$$

Firstly, Value-Added *VA* is a composite of Labour and Capital. Secondly, Energy and Value-added yield a new composite *VAE* which in turn is aggregated with Materials to produce domestic output. Factor efficiency is input specific and represented by A_i for each of the capital. labour and materials inputs and remains constant in the simulations. Energy efficiency gains take place in the energy composite and are reflected by the parameter τ . The materials and energy composites in (A.2) are obtained as Leontief fixed coefficients of the 11 non-energy and 5 energy goods, respectively. Future research will relax the latter assumption introducing imperfect substitution between primary and secondary energy inputs (Böhringer *et al*. 1997) and between renewables a non-renewable.

Non-produced inputs: Primary inputs

The CGE model is a short-run model where the supply of capital is fixed but mobile among sectors. In the labour market, however, there is unused labour. In incorporating this feature we have considered different labour market scenarios, namely, a competitive labour market where unemployment is voluntary and a scenario under which involuntary unemployment is modelled by specifying a wage curve.

Competitive Labour Market Scenario: Voluntary Unemployment

Under the scenario of perfectly competitive labour markets, there is perfect information about wages and job conditions. The workers' skills and thus the workers' characteristics demanded by firms are completely identical. Unemployment is usually considered in this type of labour market scenario as leisure that provides some utility and, when unemployment benefits exist, some income too. Following the analysis of Pisarides (1998), leisure ($\overline{L}u$). i.e. a part of the total time endowment, ($\overline{T}$) and total nominal net income earned by offering labour services in the market (R_L) are imperfect substitutes for households. The upper nest utility function whose arguments are labour real net income and time devoted to leisure is under this approach defined as:

$$UT = B\left[\theta R_L^{\frac{\psi-1}{\psi}} + (1-\theta)(\overline{L}u)^{\frac{\psi-1}{\psi}}\right]^{\frac{\psi}{\psi-1}} \qquad \text{(A3)}$$

with:

$$R_L = \left(\omega / ipc\right)(1-Tl_H)(1-u)\overline{L}$$

Where $\left(\omega / ipc\right)$ and Tl_H represent respectively the real wage and the marginal rate of social security contributions paid by the employees. $(\overline{L}-\overline{L}u)$ is, by definition, labour supplied.

According to (A3) the optimal amount of labour supplied by households is then given by:

$$L = \left(\overline{L}u\right)\left(\frac{\theta}{1-\theta}\right)^{\psi}(1-\upsilon)^{\psi}\left[(\omega / ipc)(1-Tl_H)\right]^{\psi-1} - \upsilon \qquad \text{(A4)}$$

Where υ refers to the ratio between the unemployment benefits, b_u, and the real net wage.

Wage Curve: Involuntary Unemployment

We incorporate this feature using a wage curve (Blanchflower and Oswald, 1990, 1994) that reflects the relationship between real-wages ω / CPI and unemployment u. While the total endowment of labour is given and fixed, its use in production activities is not. Thus unemployment is endogenous in the model. The specification of the wage curve is given by:

$$\frac{\omega}{CPI} = u^{\theta} \tag{A.5}$$

where θ is a parameter governing the relationship between the real wage and the unemployment rate.

Corporations

The Corporations' account in a SAM reflects the empirical reality that business surplus is not always fully distributed in first instance to asset holders as capital income. Part of it is assigned as property income and this account keeps track of these transfers to avoid leakages in the SAM. Its role in the subsequent modelling is immaterial. Since any account in a SAM can be seen as a budget constraint, we will stick to this tradition for the inflows and outflows of this especial account. In the model, this account plays a simple "book-keeping" role and its function is merely to pick up some adjustments in the income-expenditure flows:

$$(1 - t_{IT}^{CP}) r\overline{K}_{CP} + \sum_{a \in A} \overline{NT_{CP}^{a}} = P_I S_{CP} \tag{A.6}$$

In expression (A.4) t_{IT}^{CP} is the Corporations' income tax rate. $r\overline{K}_{CP}$ is the Value of their fixed capital services endowment. $\sum_{a \in A} \overline{NT_{CP}^{a}}$ represent the income distribution operations and $P_I S_C$ is Corporations' Savings. i.e. the non-distributed surplus.

Households' demand: A Linear Expenditure System.

Households' demand comes from a two-stage decision process. In the first one. consumers assign disposable income m_H to aggregate consumption C and savings S_H using a Cobb-Douglas aggregator:

$$U(C, S_H) = C^{\alpha} S_H^{(1-\alpha)} \tag{A.7}$$

Consumption behaviour proper is represented by a linear expenditure system (LES) with utility function:

$$U_C = \Pi_{i=1}^{N}(C_i - \overline{c}_i)^{\delta_i} \tag{A.8}$$

C_i stands for consumption of good i whereas $\overline{c}_i$ denotes the minimum or "subsistence" consumption. Maximising the LES utility under the assigned income to consumption, αm_H yields the LES demand system:

$$C_i = \overline{c}_i + \frac{\delta_i}{P_i}\left(\alpha m_H - \sum_{j=1}^{N} P_j \overline{c}_j\right) \tag{A.9}$$

Facing an income tax rate of t_H, disposable income turns out to be:

$$m_H = (1 - t_H)\left(R_L + r\overline{K}_H + NTH + b_u \omega \overline{L} u\right) \tag{A.10}$$

The first two terms are households' factor rents from selling labour and capital in the factors markets. The third term is net transfers to the household. and the fourth term represents unemployment benefits.

Government

The government collects taxes from consumption, production and income generation. This tax revenue T along with the income generated from the government capital endowment $r\overline{K}_G$ allow the public sector to buy goods for public consumption G_C, finance public investment G_I and undertake net transfer operations with other agents in the economy G_{NT}. Thus government's savings S_G is endogenous and equal to its deficit G_D (or surplus. if positive):

$$S_G = G_D = T + rK_G - G_{NT} - G_C - G_I \tag{A.11}$$

Foreign Sector and Macroeconomic Closure Rule

Since Spain is an open economy, its trade balance might be positive (surplus) or negative (deficit). Furthermore, macroeconomic consistency rules establish that the trade balance has to be translated into foreign sectors' savings S_{XM}, which is a component of total savings.

$$S_{XM} = P_X(X^M - \overline{E}^X) + NTX(P_X) \tag{A.12}$$

The external sector's savings corresponds to the difference between total imports X^M and total exports $\overline{E}^X$ in value terms plus deflated net transfers from the foreign sector $NTX(P_X)$. The price of the trade balance P_X is a price index that refers to a weighted average of traded goods valued at final gross prices.

The model's macroeconomic closure rule refers then to the balance between investment and savings. Total investment is determined by all economic agents' savings and is given by:

$$S = I = S_{CP} + S_H + S_G + S_{XM} \tag{A.13}$$

Total investment is sectorally distributed in turn using a fixed coefficient technology.

Equilibrium

Equilibrium in the economic flows results in the conservation of both product and value. Neither product nor value can appear from nowhere or disappear from the economic system. Product and value resources must equal their uses. These accounting rules constitute the core of the Walrasian general equilibrium concept.

In our model equilibrium is described by a vector of prices P^* for the N commodities. factors' prices (ω^*, r^*), a vector X^* of total output a level of gross capital formation I^*, a level of public deficit S_G^* unemployment rate u^*, and a level of tax revenues T^* that fulfil the following equilibrium conditions:

i) Markets for all goods clear: Total equilibrium output is fully used in intermediate demand, households' demand, gross capital formation. public demand and net exports:

$$X^* = AX^* + C(P^*, \omega^*, r^*, u^*) + I^* + G_C + \overline{E}^X$$

ii) The market for capital clears. The market for labour may not clear but demanded labour is equal to adjusted labour endowment by unemployment:

$$\overline{K} = K^d(\omega^*, r^*, X^*)$$
$$\overline{L}(1-u^*) = L^d(\omega^*, r^*, X^*)$$

iii) Total tax revenues T^* coincide with total tax payments TP by all agents facing direct and indirect taxes: $T^* = TP(\omega^*, r^*, u^*, X^*)$. Tax payments depend upon the different tax bases, which are endogenously determined.

iv) Total investment equals total savings: $I^* = S_{CP} + S_H + S_G + S_{XM}$

Equilibrium conditions i)-iv) refer to the product conservation principle. The last condition, condition v) relates to the value conservation principle.

v) The final price of each commodity in the economy must equal the sum of the values of all the inputs used to produce it. The value conservation principle simultaneously reflects the constant-returns-to-scale assumption and perfect competitive markets. Thus in equilibrium producers make zero profits and prices coincide with average costs.

Because of Walras' Law we need to select a *numéraire* to solve the system for relative prices. The selected price is capital's net rental price.

Emissions of CO_2

There is a direct "technological" link between the level of economic activity and the level of carbon dioxide emissions. The emissions technology follows a Leontief function form where emissions levels in tones per unit of output are fixed. We only consider CO_2 emissions generated in domestic production activities and in domestic final demand ruling out in this last case any exported emissions (through any energy exports). In fact this by-product from economic activity represents almost 98 percent over total pollutant emissions levels.

Exogenous elasticities

Calibration from the SAM requires the adoption of some exogenous elasticity values. We borrow these values from econometrics studies. The Armington elasticities in are average values over all European members taken from Hertel (1997) and Németh et al (2008). Elasticity values for energy goods are closed to 1.7 while for non-energy goods the average value is 0.9. thus very close to a Cobb-Douglas elasticity. The substitution elasticity for Labour and Capital is set to 1.26 and taken from Hertel (1997). The relevant parameter for the labour supply function under the competitive labour market scenario is ψ. There are no direct estimates of this parameter in the empirical literature for the Spanish economy. Therefore though we have used an initial value of 1.2[7] a sensitivity analysis has been carried out in our study. The calibration of the wage curve uses a value of $\beta = -0.13$ as reported for Spain in Sanromà and Ramos (2003). On the consumption side the income elasticities in the LES subsytem are based upon the estimates in Theil *et al* (1989). The also needed Frisch (1959) parameter in the demand subsystem is adopted from the estimates by Lluch *et al* (1977) for the European Union and set equal to -2.07. More data details are available upon request.

[7] Following Ballard (1999), this parameter might be indirectly estimated from the elasticity of labour supply. This author considers that reasonable values for this parameter are 0.1 for the case of the compensated elasticity of labour supply and 0.3 for the uncompensated elasticity of labour supply. The initial value of the parameter ψ stems from these considerations.

Table AP.1. Sectorial breakdown for Spanish I/O 04 Data

Sectors Code	Classification	Sectors	NACE-93 code
E1	Energy Sectors	Extraction of Anthracite. Coal. Lignite and Peat	10
E2		Extraction of Crude. Natural Gas. Uranium and Thorium	11-12
E3		Coke. Refinery and Nuclear fuels	23
E4		Production and Distribution of Electricity	401
E5		Production and Distribution of Gas	402-403
I1	Non-Energy Sectors	Primary Sector	01. 02. 05
I2		Other Extractive Industries	13-14
I3		Water Sector	41
I4		Food. Beverage. Tobacco. Textile and Leather	151-152. 154-155. 156-159. 16-19
I5		Other Industrial Sectors & Recycling	20-22. 37
I6		Chemistry Industry. Rubber and Plastic Industry	24-25
I7		Manufactures: Minerals. Furniture. Metallics & Electronic Products.	261-268. 27-36
I8		Construction	45
I9		Commercial & Transport Activities	50-52. 61-62. 601-603. 63.1-63.2. 63.4
I10		Market Services	65-67.70-72. 74. 80. 85. 90. 92. 93. 63.3
I11		Non Market Servicies & Public Administration	75. 80. 85. 90. 92