Preliminary draft June 2004

Can a carbon permit system reduce Spanish unemployment?[1]

by

Taran Fæhn*, Antonio G. Gómez-Plana** and Snorre Kverndokk***

Abstract:
This paper analyses whether recycling revenues from carbon emission permit auctions may reduce unemployment in the Spanish economy. We use a CGE model that includes a matching model with two types of labour, and that allows for different pricing rules and returns-to-scale assumptions. We find that abatement reduces unemployment, first of all due to beneficial impacts of recycling the revenue from permit sales. Unemployment is more effectively abated when revenues are used to reduce labour taxes rather than indirect taxes. The best option is to reduce payroll taxes for skilled workers, because they tend to work in the most labour-intensive industries, which also have low carbon emissions. Revenue recycling also reduces abatement costs in terms of welfare significantly, though none of the recycling schemes we simulate succeed to offset the welfare loss completely.

JEL classification: ***D58, J68, Q38.***

Keywords: *Spanish unemployment; Tax reform; Emission Permit Auctions; Employment dividend; Matching functions; Increasing returns to scale; Computable general equilibrium models.*

* Research Department, Statistics Norway, P.B. 8131 Dep, 0033 Oslo, Norway. Tel +47 21094847, fax +47 21094973, e-mail: taran.fahn@ssb.no.

** Public University of Navarre, Department of Economics, Campus de Arrosadía, 31006 Pamplona, Spain. Tel. +34 948 169348, fax +34 948 169721, e-mail: agomezgp@unavarra.es.

*** Corresponding author: Ragnar Frisch Centre for Economic Research, Gaustadalléen 21, 0349 Oslo, Norway. Tel. +47 22958811, fax +47 22958825, e-mail: snorre.kverndokk@frisch.uio.no.

[1] We are indebted to comments from Brita Bye, and to the Norwegian Research Council for partly financing the project.

1. INTRODUCTION

Spain, as part of the EU, has ratified the Kyoto protocol, which aims to reduce greenhouse gas emissions in industrialised countries by 2008-12.[2] Though the burden sharing agreement within EU allows Spain to increase emissions by 15% in this period compared to the 1990 level, a fulfilment of the commitment will require significant reductions compared to a business-as-usual scenario. In fact, by having increased the carbon dioxide (CO_2) emissions by 38.8% from 1990 to 2001, Spain's deviation from EU's intermediate emission goals was more serious than for most other EU countries; see Commission of the European Communities (2003). Spain will introduce revenue-raising emission permits in 2005, as part of the EU emission permit program. There is deep concern for the social costs of such measures. In particular, the debate has focused on the consequences in terms of lost competitiveness and subsequent unemployment. Spain has faced a severe unemployment problem since the last part of the 1970s. By the mid 1980s and also by the mid 1990s, the unemployment rate exceeded 20%. In 2002, the average rate had decreased to 11%, with the rate among unskilled labour being the double of that of skilled. Still, this is still among the highest unemployment rates in the EU25. These facts make the case of Spain special in a European context, and call for detailed studies of this country and its institutions in order to address the economic consequences of Spanish carbon policy.

Social costs of green taxation or, equivalently, a free market for emission quotas, have been extensively studied both in terms of welfare and employment. The tendency is, however, to study welfare effects in a Computable General Equilibrium (CGE) framework that leaves out labour market imperfections, while employment effects are addressed in shorter-term econometric models with no consistent measure of welfare changes. In fact, the welfare and employment effects are highly interlinked. Results on employment are important determinants for the welfare results, both because unemployment represents waste of resources and because high labour taxes tend to generate too strong incentives for (voluntarily) devoting time to leisure (Bye, 2000). The aim of this paper is to measure welfare and employment effects for the Spanish economy within a consistent framework, by applying a CGE model that incorporates the specific labour market characteristics of Spain. Such a combined approach is rare in the literature, and though integrated models of the EU as an entity have been applied (Carraro et al., 1996), the outstanding Spanish case, in detail, is still not addressed.

One branch of the literature has sought for the possibilities of a *double dividend* from green policies, i.e., economic gains in addition to environmental benefits that may entirely (strong dividends) or partly (weak dividends) offset the costs caused by introducing green tax wedges. Welfare dividends may occur if introducing green taxes works to moderate the welfare losses of other, existing, distortionary taxes, or it may be obtained by using revenues from the green taxation to reduce such tax wedges. For a recent survey, see Schöb (2003). Dividends in terms of employment have also been much in focus, especially in the European debate. Mors (1995), Majocchi (1996), and Bosquet (2000) all survey quantitative studies, mainly for the EU countries, and the general conclusion is that there seems to be positive, though small, employment effects of shifting taxes from labour to energy/environment. Dréze and Malinvaud (1994) suggest redirecting the fiscal revenue of European environmental taxes by reducing labour taxes for unskilled workers, only. The first empirical assessment of such a scheme is performed in (Bosello and Carraro, 2001), who turn this idea down; the employment effects are larger when taxes are reduced for all labour. In light of the distributional aspects of the high Spanish unemployment of unskilled workers, this question is of special interest for Spain. Our aim is to explore the role of various directions of recycling the revenue into the Spanish economy, including reducing the pay roll tax on all labour, exclusively reducing it on, respectively, unskilled and skilled labour, as well as reducing the *VAT* rates.

The scope for employment dividends, as well as welfare dividends, depend on the features of the labour markets, in particular their flexibility and wage formation. In many respects Spain's labour market institutions and unemployment problems are special. Dolado et al. (1998) stress the relatively high weight of unskilled unemployment in Spain compared to the EU average. Blanchard *et al*. (1995) identify the main reasons for the high unemployment to be the collective structure of wage bargaining combined with high employment protection for part of the labour force. Bover et al. (2000) also emphasise the role of generous unemployment benefits. In addition, there are large regional unemployment differences, due to a relatively low mobility of labour across regions. Another common argument is that large wedges between take-home pay and the cost of labour hamper employment. Payroll taxes are high in

[2] Since 10th March 2004, all countries in the EU have included the Kyoto Protocol obligations in their legal systems.

Spain (see, e.g., Gómez-Plana, 1999), and lowering the wedges may reduce labour costs and encourage Spanish employment.

We represent the mechanisms of the Spanish labour market as matching processes, and distinguish between skilled and unskilled workers, due to important differences both in supply and demand, and thus in policy responses. The labour supply is endogenous, and we are thus able to separate employment effects from adjusted supply behaviour and changes in the number of unemployed, respectively. Matching processes and mismatch seem to describe the Spanish labour markets well. There is a highly intensive matching process in the Spanish labour market. In 1996, there were more than 8.5 million hires out of a labour force of 16 millions (Castillo et al., 1998). This is mainly due to a high number of workers hired under fixed-term contracts (31.7% in 2001 while the EU average was 13.4%). These contracts are most prominent among less educated (Toharia, 1996). Low geographical mobility also causes a significant mismatch problem. Matching models can, as well, represent the frictions caused by presence of labour unions. Bosello and Carrari (2001) model the labour market based on assumptions on union bargaining power. This is a good approach for some European countries, but as the Spanish labour market is characterised by a gap between a very low unionisation rate and the bargaining coverage rate (Blau and Kahn, 1999, p. 1418), the union bargaining power approach is less suitable for Spain. We follow the matching specification in Balistreri (2002), which is a new way of introducing equilibrium unemployment in CGE models. Our model also takes into account that market power is prevalent in several Spanish industries, not least in the emission-intensive productions of energy and of transportation (Huergo, 1998). We quantify the impact of imperfect competition and increasing returns to scale on the results.

The paper is organised as follows. In the next section, we describe the design of the analysis and the employed model. Results are given in Section 3, which also provides sensitivity analyses. The final section concludes.

2. METHOD

2.1 The design of the analysis

We perform our analysis based on simulations on a large-scale CGE model for the Spanish economy. The main question posed in this analysis is whether an employment dividend can be reaped from establishing a restricted market for carbon permits in Spain, given that the government collects the revenue and recycles it back to the economy. We focus on the role of revenue recycling in reducing the unemployment rate. Employment dividends are defined in terms of unemployment rate reductions, in order to account for changes in both labour demand and supply. We also examine possible welfare dividends, i.e. gains in welfare besides abating CO_2 emissions that follow these reforms.

These problems are addressed by simulating reductions in the number of emission permits from the benchmark level. We present the results of 25 percent reductions.[3] The benchmark price for permits is zero, but when permits become scarce firms begin to bid for them and the price increases. This can be interpreted as an open auction of permits with a uniform price (or equivalently, carbon taxation).

We simulate five recycling alternatives:

- **Case A:** Lumpsum transfers to households,
- **Case B:** Reduced payroll tax rates for all labour, irrespective of skill levels,
- **Case C:** Reduced indirect taxes, exemplified by the VAT rates.
- **Case D:** Reduced payroll taxes exclusively for unskilled labour.
- **Case E:** Reduced payroll taxes exclusively for the skilled.

As lumpsum recycling is, by definition, undistortionary, the simulation in **Case A** is useful for cultivating the pure effects of introducing a price on emissions (*the pure abatement effects*). Comparing the other, more policy-relevant, recycling cases with **Case A** enables us to isolate the contributions of the recycling schemes (*the recycling effects*). Comparing the different recycling schemes in **Cases B, C, D** and **E** will illuminate how recycling should be directed in order to minimise unemployment and reveal to what extent the reforms are associated with tradeoffs between welfare and employment dividends.

We close the analysis by investigating the sensitivity of our results to model characteristics and parameter assumptions. Firstly, we identify the role of the imperfect competition assumption by comparing the results with corresponding results from a Constant-Returns-To-Scale (CRTS) model with perfect competition. While many CGE models used in the double

---

[3] Smaller as well as larger reductions show the same qualitative results and all variables react smoothly to the variations in emission restrictions.

dividend literature are calibrated to a CRTS model, much empirical work cast doubt on this assumption. Finally, we test the sensitivity of our results to different estimates of the externality parameters in the labour market matching functions, which should be considered uncertain. We compare the outcome of using deviating estimates from two Spanish studies, Burda and Wyplosz (1994) and Castillo *et al.* (1998).

In order to give a better intuition and be able to decompose the results of the large-scale model, a stylised, reduced form of the model is also presented. The miniature model reflects the major mechanisms in the large model and makes them more transparent. The main characteristics of the numerical model are outlined in section 2.2. For details see Appendices 1, 2, and 3. Section 2.3 derives the miniature model and visualises it in a 2-equation diagram.

2.2 The numerical model

The numerical model is a static CGE model, where the main refinements are made in order to capture the relevant welfare and employment outcomes for the Spanish economy of changes in carbon policy and labour taxation. In particular, the model incorporates important features of the Spanish imperfect labour markets, a comprehensive description if the existing tax structure, imperfect competition and other distortionary wedges within the Spanish economy, as well as disaggregate structures of household utility, production and factor use, in order to represent relevant substitution possibilities decisive to the policy responses. The model also computes CO_2 emissions on a detailed level both from firms and households.

Spain is a small, open economy that faces fixed world prices. Goods are differentiated by origin (domestic and foreign), according to the Armington assumption. The balances of trade and financial cross-border flows are fixed. This avoids continuous net capital flows in or out of the country, even if these may be unrealistic assumptions on a year-to-year basis. All agents, except the public sector, have optimising behaviour. The aim of the public sector is to balance revenues according to an exogenous restriction, which we keep constant, i.e. all policy changes are revenue neutral. A macroeconomic restriction fixes public investment and deficit (or surplus), implying that public savings are also exogenous. Included in the public income are revenues from market sales of CO_2 permits. In the benchmark, the shadow price of emission permits is zero, representing that permits are not scarce.

Primary factor endowments are given and mobile across industries, and factor markets 9-clear by adjustments in factor prices. However, the fact that labour markets far from clear in the Spanish economy is taken care of by allowing for equilibrium unemployment (see below). In macro, savings are fixed, and investments and savings balance. The production sector is specified by 16 industries (see Table 1). Firms maximize profits subject to a production technology characterised by a detailed, nested structure (see Figure 1). CO_2 emissions from firms originate from the use of fossil energy as input factors. In our static framework, investments show their influence on the economy as a component of final demand.

In order to model that market power is prevalent in several Spanish industries, the degree of competition is allowed to vary among industries, according to the degree of firm concentration: High concentration (high Herfindahl indexes) corresponds to less competitive sectors. The higher concentration, the higher mark-ups. This pricing rule is based on the idea that firms face demand functions with a negative slope as well as Cournot competition, i.e., firms take the supply of the others as given when deciding their own production. The pricing rule is obtained from the first-order condition for profit maximization, given increasing returns to scale due to the existence of some fixed labour and capital costs. All firms within an industry are identical. There is free entry and exit of firms in each sector, so that in equilibrium profits are zero, and price equals average costs, inclusive of the fixed costs.

Defining the mark-up as the price-cost margin (P-MC)/P = MARKUP, and using that, in equilibrium, price is equal to average cost (P = AC), we find that MC/(1-MARKUP) = AC. This mark-up is specified as follows:

$$MARKUP_i = \frac{\Omega_i}{E_i \kappa_i^d}, \; i=1,\ldots,16$$

This is the Lerner index for sector *i*, and depends on three variables: The conjectural variations parameter Ω_i (in our case: $\Omega_i = 1$[4]), the perceived elasticity of demand faced by sector *i* (κ_i^d), and the share of a typical firm in sector *i*'s output, that is equal to the inverse of the number of firms in each sector ($1/E_i$). This share can be proxied in the benchmark by the Herfindahl index (see Appendix 3), under the assumption of symmetric firms in each sector. To be able to study the influence of imperfect competition, in isolation, we compare the

[4] Usually conjectural variation is defined so that it is equal to zero with Cournot competition. However, here the conjectural variation parameter is normalized to unity.

outcomes of this model with simulations on a model version where all firms exhibit constant returns to scale and marginal cost pricing.

Private households are assumed to share homothetic and identical preferences. Hence, they can be represented by a single, representative household. The household maximizes a nested welfare function (see Figure 2), by choosing savings[5], leisure and consumption of goods (including energy). Households generate CO_2 emissions when they consume coal, oil and gas. However, the quality of the environment is not specified in the welfare function. Endowments of capital and skilled, as well as unskilled labour, are fixed. The labour supply is elastic up to these fixed maximum amounts. This feature of the model enables us to analyse to what extent adjustments of labour supply explains changes in the unemployment rates.

Based on Balistreri (2002), we assume a case of equilibrium unemployment, inspired by a matching specification and the theory of external economies (see, e.g., Markusen, 1990). A matching function gives the number of jobs mainly formed as a function of the number of workers looking for a job (unemployed), the number of firms looking for workers (vacancies); see, e.g., Petrongolo and Pissarides (2001) for a recent survey of the matching function in macroeconomics. With this approach, frictions, due to, e.g., lack of information, immobility, search costs, or heterogeneities across workers and jobs, are important to explain the existence of unemployment or vacancies. Following Balistreri, we model frictions by assuming that workers have to spend some resources to find a job; the search process is costly. We assume that all search costs are borne by the workers. This means that real received wages, net of taxes, W^j, include a premium ($\frac{1}{H^j} > 1$) on reservation wages (W^j_0) that represents search costs,

$W^j = W_0^j \frac{1}{H^j}, j = s, us$, where s = skilled, us = unskilled workers.

Another feature with Balistreri's approach is externalities. The unemployed views the search cost as given. However, the risk of not being matched, represented by the search cost, is affected by the behaviour of all other agents. If, for instance, the labour market expands, labour demand increases and the cost of participating in the market falls; it is easier to find a job. If the unemployment rate increases, vacancy congestion decreases and, therefore, the

[5] Given our static approach, we consider a unitary elasticity of substitution between consumption and savings (see Howe, 1975). Savings can be interpreted as the purchase of bonds for future consumption.

matching process eases. We model this by assuming that the *H*-functions (inverse premium) has properties similar to matching functions:

$H^j = \left(1-\overline{U^j}\right)\left(\frac{LD^j}{\overline{LD}^j}\right)^{\eta_0}\left(\frac{U^j}{\overline{\overline{U}}^j}\right)^{\eta_1}, j = s, us$, where a bar denotes a benchmark value for the referred variable, *LD* is aggregate demand for labour and *U* is the unemployment rate. *H* is increasing in *LD* and *U*, i.e. the search cost is decreasing in the same variables. Following Balistreri (2002), vacancies are, for simplicity, absent in this model, and labour demand is used as a proxy. This means that total employment follows the labour demand curve. η_0 is the elasticity with respect to vacancies. It measures the positive externality caused by firms on searching workers, here represented by a lower search cost. η_1 is the elasticity with respect to unemployment and measures the positive externality from workers to firms.

The model is solved through Rutherford's (1999) method, which treats general equilibrium models as mixed complementarity problems following Mathiesen (1985), and is implemented with GAMS/MPSGE. It has been calibrated using the Spanish Social Accounting Matrix for 1990, MCS-90, developed in Uriel *et al*. (1997) and Gómez-Plana (2001), as the reference equilibrium. Elasticities are taken from available empirical evidence. See Appendix 3 for more information on calibration and data.

2.3. A stylised, reduced-form miniature model

As a tool for the analysis in the next section, we use a reduced-form, less specified representation of the model. It suppresses many details of the model, for instance the dual labour market is aggregated to one, and the product markets are, as well, merged. In Eqs. (1) to (4) the equilibrium of the stylised model is expressed by only four equations, the indirect welfare function, the capital and labour market equilibriums, and the trade balance. All other equations and equilibrium conditions, such as the product market equilibrium and the public budget constraint, are implicitly defined:[6]

(1) $WF = WF^*\{Q_{cg}(W, R, U; \varepsilon), L^S(W, R, U; \varepsilon)\} = WF(W, R, U; \varepsilon)$

(2) $\overline{K} = K^{D*}\{W, R, \varepsilon, X[W, R, \varepsilon, Q_{cg}(W, R, U; \varepsilon)]\} = K^D(W, R, U; \varepsilon)$

(3) $L^S(W, R, U; \varepsilon)(1-U) = L^{D*}\{W, R, \varepsilon, X[W, R, \varepsilon, Q_{cg}(W, R, U; \varepsilon)]\} = L^D(W, R, U; \varepsilon)$

[6] A detailed presentation of the stylised model and its reduction into four equations is available from the authors on request. See also Fæhn and Grünfeld (1999) for a more extensive presentation of a similar procedure.

(4) $\overline{D} = D^*\{W, R, \varepsilon, Q_{cg}(W, R, U; \varepsilon)\} = D(W, R, U; \varepsilon)$

Notation:

WF = welfare

Q_{cg} = demand for aggregate consumption of goods

W= the labour rent = the wage rate

R= the capital rent = the user cost of capital

U= the unemployment rate

$\overline{K}$ = fixed total capital

K^D= capital demand

L^D= demand for labour

L^S= supply of labour

X= domestic output

$\overline{D}$ = fixed trade balance

ε= vector of exogenous variables

Eqs. (1) express that welfare is defined as the utility of demanded consumption goods, including exogenous savings, and demanded leisure, which is implicitly a function of labour supply, L^S (see Eqs. (A17) and (A20)). Demand for the final good and supply of labour are both determined by prices and income. Eqs. (1) exploit that prices and income are implicitly determined by the factor prices W and R, the unemployment rate, U, which affect the income of the aggregate household, as well as the vector of exogenous variables, ε which includes, *inter alia*, exogenous income components, tax rates, world market prices, and the exogenous emission restriction that determines the quota price, see Eqs. (A31).

According to Eqs. (A5) in the numerical model, equilibrium capital demand, K^D, is restricted to the given capital stock, $\overline{K}$. This is ensured by Eqs. (2), above. The first appearance of W, R and ε in the K^{D*}- function represents changes in relative demand of labour and capital of altering wages, capital rents or exogenous variables (*Substitution effects*). The second represents the effects on domestic output of altering production costs through changes in the same variables (*Competitiveness effects)*. Output is also affected by demand for the final good, Q_{cg}, which again is a function of the factor prices, the unemployment rate and exogenous variables (*Home market effects)*.

The unemployment-adjusted labour market equilibrium is represented in Eqs. (3), which correspond to Eqs. (A6) and (A7) of the numerical model. *Labour supply effects* are induced by changes in *W*, *R*, *U* and ε, as described for Eqs. (1). The term *(1-U)* captures that the unemployment rate influences the labour market equilibrium directly (*Unemployment wedge effect*). In the determination of the labour demand, L^D, we recognise the analogous *Substitution effects*, *Competitiveness effects* and *Home market effects* as for K^D.

Eqs. (4) restrict the net current account by fixing the trade balance to $\overline{D}$. The corresponding restriction is expressed in Eq. (A.27) in the Appendix. The current account is influenced both directly by the factor prices and ε (*Competitiveness effects*) and through import leakages following the domestic final consumption, Q_{cg} (*Home market effects*), quite analogous to these effects in the Eqs. (2) and (3).

The four equations solve for the four endogenous variables *WF*, *W*, *R* and *U*. We can reduce the model further, by solving Eqs. (1) for *W*, Eqs. (2) for *R*, and then inserting the latter into the former. For a given ε, *W* and *R* are determined by *WF* and *U*:

(1'): $W=W(WF, U; \varepsilon)$

(2'): $R=R^{*}(W, U; \varepsilon)= R(WF, U; \varepsilon)$

Using Eqs. (1') and (2') leaves us with the labour market equilibrium and the current account expressed in Eqs. (3) and (4) as functions of only two endogenous variables, *WF* and *U*, which again implicitly determine all other variables in the model. In Eqs. (3) partial increases in *WF* work through factor prices, only (see Eqs. (1') and (2')). Increases in *U* influence Eqs. (3) through the same factor price channels. In addition, it reduces consumer income, inducing a positive *Labour supply effect* and a negative *Home market effect*, and it reduces the term *(1-U)*, i.e. the *Unemployment wedge effect*. *WF* also influences the current account in Eqs. (4) via factor prices, exclusively. *U* affects through factor prices, but in addition it has a direct *Home market effect;* the higher *U*, the lower the income of the representative household and the smaller the home market demand.

Shift analyses on this two-equation version of the model will directly give us the resulting welfare and employment dividends, i.e. the endogenous changes in *WF* and *U* resulting from the CO_2 policy reforms. In Figure 3, the two-equation model is presented. The LL^0-locus and the DD^0-locus are defined as the combinations of *WF* and *U* that for the exogenous benchmark values, ε^0, fulfils Eqs (3) and (4), respectively. Where both conditions are fulfilled we find the equilibrium solution of the model in the benchmark case, i.e. in the intersection coordinate (WF^0, U^0). We have simulated the numerical model[7] in order to identify the slopes, i.e. the necessary change in *U* for different, exogenous shifts in *WF*, keeping, respectively, the labour market equilibrium and the trade balance intact.

The positive slope of the LL locus implies that in the Spanish economy a distortion in the labour market equilibrium resulting from a given relative *increase* in *WF* will have to be neutralised by a simultaneous *increase* in *U*. The explanation is that increased *WF*, in isolation, creates a labour supply surplus, while an increase in *U* creates a deficit, which rebalances the labour market. To start by explaining the partial effects of *WF*, it works, as already pointed out, through factor prices. Simulations on the numerical model show that the strongest impact of *WF* on factor prices comes through the indirect utility expressed by Eqs. (1): A rise in *WF* will have to involve real income improvements, and for given *U*, factor price increases must take place. The simulations show that a partial rise in *WF* causes wages to increase relatively more than capital rents, and nominal wages more than the prices of consumption goods so that the real wages increase. In the following we suppress the effects on capital rents, as they only work to dampen the conclusions from a discussion focusing on nominal and real wages.

Implications in the labour market from increased nominal and real wage rates (through increased *WF*) are:

i) *Labour supply effects:* The household reacts to higher real wages by increasing labour supply.

ii) *Substitution effects:* Increased wages tend to encourage a substitution of capital for labour and reduce labour demand.

iii) *Competitiveness effects:* The competitiveness of domestic firms deteriorates and brings about a labour demand fall.

iv) *Home market effects:* Demand for goods, and thus the induced labour demand, increases.

[7] For simplicity, in these simulations the labour market has been merged into one in the numerical model, in order to operate with only one unemployment rate, wage rate etc.

As already pointed out, the simulations of the numerical model reveals that the net effect of *i)* to *iv)* is to create a labour supply surplus, implying that *iv)* is inferior. In other words, moving rightwards from a point on the LL locus (for given *U*) produces a labour supply surplus. The conclusions reflect characteristics of the Spanish economy. *Competitiveness effects* and *Substitution effects* contribute the most. Though the Armington elasticities are not very high - cf. Table A3 - the fact that internationally competing industries are relatively labour intensive (particularly metal production contributes to this) cause significant *Competitiveness effects* of increased wages. The *Substitution effects* are less easy to track, but the substitution elasticities listed in Table A3 indicate rather responsive labour-to-capital rates at the firm level. Counteracting *Home market effects* cannot be ignored. A real wage increase induces both substitution and income effects in favour of increased consumption. The effect on labour demand is, however, somewhat weakened by the fact that consumer goods are relatively capital intensive - and becomes even more so when prices of labour intensive goods increase in relatively terms. First of all consumption of trade services, other manufacturers and renting contribute to the high capital intensity.

The responding *rise* in *U* in order to neutralise this excess supply is due to a dominating:

v) *Unemployment wedge effect:* The term *(1-U)* in the Eqs. (3) drops and counteracts the excess labour supply.

While the other already mentioned effects of *U* go in the other direction, another effect of *U* on wage rates, which is suppressed in the stylised model exposition, also contributes to the positive slope: Increased *U* reduces the search cost component of the wage rate directly (see Eqs. (A38) and (A39)) due to the externalities of the matching process (see Eqs. (A40) and (A41)).[8] We can conclude that for all points lying *below* the LL-locus there will be a labour supply surplus, while points off and *above* the curve represents situations with labour supply deficits.

As illustrated in Figure 3, also the slope of the DD-locus is positive, implying that *WF* and *U* work in opposite directions on the trade balance. Partially increasing *WF* rises nominal and real wages and affects the trade balance through:

vi) *Competitiveness effects:* Reduced competitiveness adversely affects the trade balance.

[8] Welfare also influences wages through the search costs, as its labour demand component implicitly depends on, *inter alia* the welfare level, but this is more indirect.

vii) *Home market effects:* Domestic income increases and encourages consumers' demand for goods, including imported goods. Increased import leakage reinforces the trade deficit.

Thus, partially rising *WF* from a point on the DD-curve deteriorates the trade balance. The upward slope implies that increases in *U* will help to re-satisfy the trade balance restriction. The dominant effect of increased *U* in the Spanish economy is to decrease import leakage through a negative *Home market effect*. Consumer goods with high (input-output-adjusted) import shares are first of all metals and other manufacturers. The reduction of search costs also contributes somewhat to strengthen the trade balance. Being off and *above* the DD-locus represents situations with smaller deficits than required by the current account restriction, while at points *below* the curve deficits are too large.

3. EMPLOYMENT AND WELFARE EFFECTS OF CARBON PERMITS

3.1 Case A: Lumpsum recycling

In order to wind up the main mechanisms producing the results in **Case A**, we exploit the stylised model presented in Section 2.3. In Figure 3, the equilibrium solution of **Case A** is marked in the point (WF^A, U^A), which represents the intersection between the loci LL^A and DD^A. The respective shifts from the LL^0 and DD^0-loci reflect that the ε-vector has changed due to the exogenous restriction of CO_2 emissions. The direct effect is to impose a price wedge between the consumer and producer price of fossil fuels. Figure 3 shows that, relative to the benchmark, both loci shift upwards in the relevant area. As explained in Section 2.3, these points are characterised by *WF*s and *U*s that, for given $\varepsilon = \varepsilon_0$, would create a labour supply deficit. In other words, the partial effect of moving from ε_0 to ε_A is to create a labour supply *surplus* that has to be neutralised. This surplus is the net result of effects through the four main channels for ε-impacts already described in Section 2.3 - confer Eqs. (3). The surplus is created by *Competitiveness effects* and *Home market effects*. The former are due to a labour demand fall as internalising costs of emitting deteriorates the competitiveness of domestic firms. The latter are consequences of lowered real wages, which discourages consumers' demand for goods and, thus, firms' demand for labour. Neither the internationally exposed goods, nor the consumer goods have very high *direct* fossil fuel intensities, but in an input-output-corrected sense the CO_2 permit prices are significant and affect prices, first of all through incidence in the markets for electricity and transport. *Labour supply effects* and *Substitution effects* contribute to weaken, but not offsetting, the labour supply surplus. Labour supply falls as real household income drops in the wake of higher consumer prices;

consumption of fossil fuels, as well as goods produced by fossil fuels, becomes more expensive. *Substitution effects* also decrease net labour supply. The capital-intensive industries tend to face the highest CO_2 permit costs, and a substitution will thus take place of relatively labour-intensive production for capital-intensive. However, as share of total capital use, the fossil fuel intensive industries are not very important, so this effect is small.

Simultaneously, the DD-locus shifts from DD^0 to DD^A. As the new (*WF*,*U*)-points lie *above* the DD^0 -locus, we know that their adjustments, in isolation, cause a current account improvement from the benchmark (see Section 2.3). For this to balance current account, the CO_2-policy reform must have caused a corresponding current account reduction. The explanation is that the lumpsum reform affects the current account through two main channels (see the ε's in Eqs. (4)): Increased emission prices imply a competitiveness loss that deteriorates the trade balance. This negative *Competitiveness effect* turns out to dominate the positive *Home market effect* caused by reduced import leakage when domestic income decreases.

The new intersection point reflects that introducing a CO_2 permit reform with lumpsum recycling reduces *U*, but at the cost of reduced *WF*. The employment dividend is small; restricting emissions by 25 percent decreases the unemployment rate of skilled labour by 0.02 percent and of unskilled by 0.03 percent (See Table 2a). The result is, nevertheless, optimistic compared to European studies, which tend to find negative employment dividends from lumpsum simulations. We find a slight increase in employment in the Spanish case (0.03 percent for skilled labour and 0.07 percent for unskilled). This rise reflects that the negative shift in the labour demand caused by *Competitiveness effects* and *Home market effects* of the CO_2 permit prices is more than offset in the new equilibrium first of all by wage drops, amounting to 1.5 percent for skilled and 1.6 percent for unskilled labour. Subsequently, workers are absorbed within the relatively labour intensive and carbon-extensive industries, most prominently *Agriculture*, *Production of metal* and *Other manufacturing* (including manufacturing of textiles and wood products). The simultaneous welfare loss amounts to 0.59 percent. This pure abatement cost lies in the lower range of those from other European studies (see IPCC, 2001, Bye et al., 2003, Bosquet, 2000). One explanation is differences in the employment results: European studies usually find that employment drops. This tends to intensify the abatement costs due to significant tax interaction effects with existing labour taxes.

3.2 Case B: Recycling through reduced payroll tax rates on all labour

Adding recycling effects of reduced payroll taxes on all labour to the pure abatement effects in **Case A** corresponds to the more policy-relevant **Case B**, which is also illustrated in Figure 3. The move from (WF^A, U^A) to (WF^B, U^B) illustrates that the isolated recycling effects of this scheme are to strengthen the employment dividend and to partly offset the welfare loss. In terms of the loci, the paytroll tax reductions change ε and cause the loci to shift to LL^B and DD^B, both lying *below* the respective locis of **Case A**. Thus, *cet. par.*, the *WF* and *U* movements would cause a net supply surplus in the labour market along with an increased deficit in the current account. Accordingly, as we are in a new equilibrium, the recycling scheme has caused the opposite: A labour supply deficit and a current account improvement. These are results of counteracting effects that can be tracked by using Eqs. (3) and (4), as above. In the labour market, *Labour supply effects* of the change in ε contribute to increase net supply, as reducing payroll tax rates lowers costs and market prices. However, this effect is inferior to the other three, which all increase labour demand and cause the supply deficit: *Substitution effects* through lowered labour prices, *Competitiveness effects* through the subsequent competitiveness improvements, and *Home market effects* through higher real income and demand. The current account improvement caused by lower labour costs is explained by the favourable *Competitiveness effects*. *Home market effects* counteract somewhat through higher import leakage, but turns out to be inferior.

Table 2b shows that the unemployment rate for skilled and unskilled labour falls by 0.15 and 0.09 percent, respectively, due to the recycling scheme. This is due to the joint positive impact of the *Substitution effects, Competitiveness effects* and *Home market effects* on labour demand compared to the lumpsum case, though demand is significantly dampened by increased wages. The nominal wage rates increase by 1.8 percent for both skill groups due to the recycling. Adding the recycling effects to the pure abatement effects reveals employment dividends of 0.17 and 0.12 percent, respectively, for the skilled and the unskilled labour (i.e. compared to the benchmark). These are relatively small effects and confirm the conclusions in the surveys of Mors (1995), Majocchi (1996) and Bosquet (2000).

The recycling effects increase welfare by 0.37 percent. Main reasons are that the substantial labour tax wedge is reduced and employment increases. Compared to the lumpsum case, employment of unskilled and skilled labour increases by, respectively, 0.23 and 0.24 percent. The welfare gain of the recycling partly, but not completely, offsets the pure abatement cost found in **Case A** and nets the welfare loss in **Case B** to 0.22 percent. Such weak double (welfare) dividends of labour tax recycling are found in most of the European studies referred to above.

3.3 Case C: Recycling through reduced VAT rates

The case of recycling revenue through VAT reductions is also illustrated in Figure 3. As for **Case B**, both loci are shifted downwards compared to the lumpsum case, indicating that the recycling effects are to generate a labour supply deficit, as well as a current account improvement. However, none of the shifts are as strong as in the case of pay roll recycling. In the labour market, positive *Labour supply effects* are outperformed by *Home market effects* and *Competitiveness effects* of lower prices that stimulate labour demand. *Substitution effects* are not prominent in **Case C**, as opposed to **Case B**. The favourable *Competitiveness effects* also explain the current account improvement.

The equilibrium of **Case C** is marked in the point (WF^C, U^C). No employment dividends are obtained from the VAT recycling, as opposed to the payroll recycling, indicating that unemployment should rather be combated through direct reductions in labour costs. The employment stimuli caused by the *Competitiveness effects* and *Home market effects* are more than offset by factor price increases, leaving employment slightly lower than in the lumpsum case, see Table 2b.

As reported in Table 2b, the weak double welfare dividend is slightly stronger in this case than in the payroll recycling case (**Case B**), indicating that there are relatively high indirect commodity taxation through VAT in Spain. I should check EU data. Similarly to payroll taxation, indirect taxation contributes to distort the choice between leisure on the one hand and labour supply and consumption on the other. The increase in consumption relative to leisure due to the VAT reductions thus contributes to the welfare improvements. Similar results are found for other countries (see the above mentioned surveys), but typically the effects on employment and welfare are weaker than in case of payroll reductions. However, in the Spanish case, the initial VAT taxation on domestic output outperforms the joint VAT and tariff wedge on imports, implying a distortion of resource allocation in disfavour of home-maid products. The relative price reduction of domestic goods resulting from the VAT recycling results in a welfare-improving increase of Spanish market shares at home.

3.4 Case D: Recycling through reduced payroll tax rates on unskilled labour

Distributional reasons could call for a recycling policy designed to stimulate unskilled labour, in particular, due to the fact that the unemployment rates are twice as high for unskilled as for skilled labour. This could also be a case for reaping higher employment dividends than in the case of non-discriminatory payroll recycling, because the relative effect on wage costs of lowering payroll taxes will be higher for unskilled labour than for skilled, due to the low wage rates of unskilled workers. However, our results contradict this hypothesis. We find no employment dividend in macro in this recycling regime, as opposed to the non-discriminatory recycling scheme in **Case B -** see Table 2b. The reason is that discriminating implies a decrease in the number of employed which is not found in the number of supplied workers. This increases the unemployment rate compared to **Case B**.

Behind these aggregate figures lie significant differences between the two skill groups. While the non-discriminatory recycling in **Case B** gained both groups (and skilled slightly more in relative terms) exclusively recycling through the costs of unskilled labour reduces the unemployment rate for this group, only. This is offset by a rise in the unemployment rate of skilled labour. The recycling effects are qualitatively illustrated in the market figures for unskilled and skilled labour in Figure 4a and 4b. In the unskilled market, the isolated effect of reducing payroll taxes is to generate positive *Labour supply effects* through price reductions, as well as positive *Competitiveness effects*, *Home market effects* and *Substitution effects* on demand. In particular, the *Substitution effects* contribute to a significantly higher demand for unskilled labour than in **Case B**. Other cost changes, primarily through factor price increases, modify the shifts. The subsequent labour supply deficit is neutralised by an increased unskilled wage rate and a reduced unemployment rate, and in the new equilibrium, the recycling scheme has contributed to increase unskilled labour wages by as much as 2.77 percent, while the unemployment rate has fallen by 0.22 percent, reflecting a labour demand increase of 0.58 percent and a somewhat weaker labour supply increase of 0.53 percent.

In the market for skilled labour, the shifts are weaker, in particular the demand shift, due to the significant counteracting *Substitution effects* away from skilled labour caused by the cost reductions of unskilled labour. Before any adjustments in the wage rate and the unemployment rate of the skilled, the labour market unbalance is less serious than in the market for unskilled labour. The equilibrium unemployment rate and wage rate for the skilled part of the labour force increase by 0.15 and 0.38 percent, respectively. The increased unemployment rate mirrors that the *Substitution effects* are strong and contributes to leave skilled labour employment 0.25 percent lower than in the lumpsum case.

When it comes to welfare, the recycling through payroll taxes on unskilled labour generates a marginally lower weak welfare dividend than through payroll taxes on *all* labour. This reflects, *inter alia*, the inter-linkages between welfare and employment. When we leave out distributional topics, the discriminatory scheme reduces welfare by decreasing in the aggregate number of employed somewhat and increasing the number of unemployed.

3.5 Case E: Recycling through reduced payroll tax rates on skilled labour

Qualitatively, the opposite story as for **Case D** applies to this case of recycling exclusively through *skilled* labour costs, and it can be illustrated simply by changing the labels of the Figures 4a and 4b. As in **Case D**, discriminating between labour groups generates strong substitution effects that explain most of the differences between the discriminatory and non-discriminatory cases, but here the opposite labour demand impulses with respect to skill groups occur. As reflected in Table 2b, wage rates for the skilled increase more than for the unskilled and the unemployment rate falls for the skilled, while that of the unskilled increases. The most interesting observation from the analysis of **Case E** is the strong employment dividend obtained in macro. The overall unemployment rate drops by 0.23 percent, which implies that recycling through skilled payroll tax rates turns out as the most recommendable scheme, and noticeably more effective than recycling though the costs of unskilled labour. This relates to the fact already mentioned that, typically, labour-intensive industries tend to use more skilled than unskilled labour. Thus, by reducing pay roll taxes on skilled we obtain not only a substitution of skilled labour for unskilled labour, but simultaneously a substitution in macro of relatively labour-intensive industries for capital-intensive. Thus, spending revenue on subsidising skilled labour stimulates skilled labour demand more than a corresponding subsidisation of unskilled stimulates unskilled labour. The fact that pay roll taxes represent a lower share of labour costs for skilled than for unskilled, counteracts but does not outweigh this. There is, however, worth noticing the adverse effects this scheme has on the distribution of the unemployment burden. In all the other cases, the recycling schemes work to reduce unemployment of the unskilled. While subsidising unskilled labour produce the greatest difference between the skill groups in terms of unemployment, it goes in favour of the relatively low-waged and low-skilled. Subsidising skilled produce the opposite result.

The weak welfare dividend of the recycling scheme is marginally higher when recycling through skilled than through unskilled pay roll tax rates. The somewhat stronger reallocation of households' time endowment from leisure to employment contributes to this. Again, it is worth emphasising that the welfare measure does not consider distributional concerns.

3.6 Sensitivity tests

Sensitivity to the competition and returns to scale assumptions

This section illustrates the contributions to the results of assuming increasing returns to scale and imperfect competition. We do this by comparing the results to the more commonly assumed case of constant returns to scale and perfect competition. In Table 3, the differences between these two regimes are reported in the case of reducing CO_2 emissions by 25 percent and recycling through pay roll taxes on both skill types. For the other recycling cases, the differences do not deviate markedly. Table 3 shows that first of all *the welfare dividend* is sensitive to the assumptions on competition and returns to scale. In **Case B'**, characterised by constant returns and perfect competition, the welfare costs of the reform are 23 percent lower than in **Case B**. The main reason for this is that scaling down production is not associated with decreasing productivity and thus renders GDP and consumption somewhat higher.

The effects on *employment* and *the employment dividends* turn out to be less significant. True, the labour demand is more elastic in **Case B'** than in **Case B**. This follows from the absence of fixed costs of production and thus increased feasibility of input substitution. In addition, the competitive firms in **Case B'** face an infinitely elastic demand in the goods markets, as opposed to the non-competitive firms in **Case B**, which face downward sloping demand curves. The higher price elasticities of demand in the markets for goods, the higher the elasticity of labour demand.[9] Nevertheless, as seen from Table 3, the employment of skilled and unskilled labour is about the same in the two model simulations, as are the unemployment rates. Due to more elastic labour demand curves the fall in employment following the CO_2 tax would increase in **Case B'** compared to **Case B**, even if the fall in production is smaller due to

[9] See Fallon and Verry (1988, pages 83-90) for an analytical demonstration, or McConnell et al. (1999, chapter 5) for an economic intuition.

absence of economics of scale. In addition, tax revenues to be recycled will be lower in **Case B'**. Thus, the reduction in pay roll taxes and thus stimulation of labour demand will be lower.

Testing the parameters in the matching function

Finally, we test the sensitivity of our results to different estimates concerning the externality parameters in the labour market matching functions. We compare the results above, based on values from Burda and Wyplosz (1994) (*BW*) with alternative estimates provided in Castillo *et al.* (1998) (*CJL*). The main difference lies in their parameter estimates for the unemployment externalities. While *BW* estimate the elasticity to 0.12, Castillo *et al.* (1998) (*CJL*) find it to be as large as 0.85. The vacancy externalities from the two studies are approximately the same, 0.14 against 0.15. The estimates imply that while the matching function used in the simulations above shows decreasing returns to scale, substituting of the parameter values from *CJL* tests for the case of a constant-returns-to-scale matching function.

Tests of the parameter values for the externalities in the matching function show that the two parameter sets produce rather similar welfare dividends, while the unemployment dividends seem less robust to parameter changes. The case of reducing CO_2 emissions by 25 percent and recycling through pay roll taxes on both skill types is reported for both sets of parameter values in Table 3.

4. CONCLUSIONS

This paper addresses the special challenges of Spain in meeting the international commitments on greenhouse gas emissions, while at the same time attend to her severe unemployment problems. Within a CGE framework, we model unemployment as a result of the matching process in the labour market, which seems to yield a good description of the Spanish labour market. This allows for studying welfare and employment dividends of carbon policies in relation, and also for taking into consideration the effects on labour supply. The endogeneity of supply has lead us define employment dividends in terms of unemployment rates instead of employment, to sort out the effects on voluntary choices of leisure.

A special contribution of our work is to account for the substantial differences between the markets for unskilled and skilled labour markets in Spain, which enables us to supplement previous studies with assessments of policy alternatives directed to one of the labour market segments, only.

We find, in line with most other studies, that a carbon permit market in Spain, combined with revenue recycling through payroll tax reductions, to increase employment, and lead to unemployment rate reductions. Our results are relatively optimistic, as adverse unemployment effects are avoided also in case of lumpsum recycling, that is when no payroll tax reductions are accounted for. This reflects first of all that carbon intensive sectors represent a low share of employment, especially of unskilled employment, so that the economy is able to absorb the workers through expansion in other, relatively labour-intensive industries.

The recycling schemes have different potentials for reducing unemployment rates. As Bosello and Carraro (2001) find for Europe, the potential for increased Spanish employment is least promising if payroll taxes are reduced for the *unskilled* labour, only. However, a case not analysed by Bosello and Carraro (2001) seems to be the most promising, namely reducing payroll taxes exclusively for the *skilled* workers. When the supply effects are taken into account and unemployment rates calculated, the employment dividends appear to be quite sensitive to the recycling scheme: While using the revenue to lower payroll taxes on unskilled labour reduces the aggregate unemployment rate by only 0.01 percent, recycling through skilled payroll taxes reduces the rate by 0,23 percent. Recycling to both groups yield an employment dividend in between (-0.10 percent). The relatively strong employment dividend from recycling through costs of skilled labour reflects that this group is relatively intensively employed in the carbon intensive industries. Reducing their payroll taxes thus smoothens the process of absorbing the resources becoming abundant within the contracting industries. This adds to the fact that the revenue from carbon taxation allows for relatively larger tax cuts per worker, as the employment of skilled workers are substantially lower than of unskilled in the Spanish economy, even in relative terms when differences in wage levels are accounted for.

This result leaves a dilemma to policy makers due its distributional implications: In spite of its stronger aggregate employment dividend, the recycling scheme will deepen the gap between the two skill groups in terms of unemployment rates. The entire employment dividend will come to the relatively advantageous and prosperous group of skilled, while the unemployment problem of unskilled workers will increase somewhat. On the contrary, reducing taxes on employment of unskilled will benefit this group, only. In spite of no aggregate employment dividend in this case, the scheme can be of interest to policy makers searching a way to generate unskilled employment.

We find no trade-off between welfare and unemployment concerns in the choice among recycling alternatives. All the analysed schemes produce nearly the same, and positive, welfare effects. However, the welfare dividend is weak, i.e. the gains from recycling the revenue cannot offset the welfare cost of introducing market prices on CO_2 emissions. We do not calculate the welfare gain obtained in terms of a better environment and a positive contribution to climate stabilisation.

It is important to bear in mind that the primary objective of introducing the carbon permit system is to reduce emissions. Ideally, other policy aims require selective and targeted instruments, in order to be addressed efficiently. No analyses of the Spanish unemployment problem put much emphasis to the payroll tax system as a major contributor to the problems. Our conclusions have only minor potential as a contribution to the Spanish labour market debate, but as relevant first of all to the Spanish carbon emission issue.

REFERENCES

Bajo, O. and R. Salas (1998): Indices de concentración para la economía española: Análisis a partir de las fuentes tributarias. *Economía Industrial*, **320**: 101-116.

Balistreri, E. J. (2002): Operationalizing Equilibrium Unemployment: A General Equilibrium External Economies Approach. *Journal of Economic Dynamics & Control*, **26**: 347-374.

Ballard, C. L., J, B. Shoven and J. Whalley (1985): General equilibrium computation of the marginal welfare costs of taxes in the United States. *American Economic Review*, **75**: 128-138.

Bernstein, P. M., W. D. Montgomery, and T. F. Rutherford (1999): Global impacts of the Kyoto agreement: results from the MS-MRT model. *Resource and Energy Economics*, **21**: 375-413.

Biscourp, P. and C. Gianella (2001): Substitution and complementarity between capital, skilled and less skilled workers: an analysis at the firm level in the French manufacturing industry. Paper presented at European Association of Labour Economists 2001 Annual Conference, Jyväskylä.

Blanchard, O., J. F. Jimeno, J. Andrés, C. Bean, E. Malinvaud, A. Revenga, G. Saint-Paul, D. J. Snower, R. Solow, D. Taguas, and L. Toharia (1995): *Spanish Unemployment: Is There a Solution?*, Centre for Economic Policy Research, London.

Blau, F. D. and Kahn, L. W. (1999): Institutions and laws in the labor market. In O. Ashenfelter and D. Card (eds.) *Handbook of Labor Economics*, volume 3, Elsevier.

Bosello, F. and C. Carraro (2001): Recycling energy taxes: impacts on a disaggregated labour market, *Energy Economics*, **23**: 569-594.

Bosquet, B. (2000): Environmental tax reform: does it work? A survey of the empirical evidence. *Ecological Economics*, **34**: 19-32.

Bovero, O., P. García-Perea and P. Portugal (2000): Labour market outliers: lessons from Portugal and Spain, *Economic Policy*, **15(31)**: 380-428.

Burda, M. and C. Wyplosz (1994): Gross worker and job flows in Europe. *European Economic Review*, **38**: 1287-1315.

Bye, B. (2000): Labour Market Rigidities and Environmental Tax Reforms: Welfare Effects of Different Regimes. In G. W. Harrison, S.E. Hougaard Jensen, L. Haagen Pedersen and T. F. Rutherford (eds.): *Using Dynamic General Equilibrium Models for Policy Analysis*, Elsevier Science B.V., Amsterdam.

Bye, B., S. Kverndokk and K. E. Rosendahl (2002): Mitigation costs, distributional effects, and ancillary benefits of carbon policies in the Nordic countries, the UK, and Ireland. *Mitigation and Adaptation Strategies for Global Change*, **7(4)**: 339-366.

Castillo, S., J. F. Jimeno and O. Licandro (1998): Employment segmentation, labour mobility, and mismatch: Spain, 1987-1993. Working Paper 98-04, FEDEA, Madrid.

Commission of the European Communities (2003): "Report from the Commission under Council Decision 93/389/EEC as amended by Decision 99/296/EC for a monitoring mechanism of Community greenhouse gas emissions", http://europa.eu.int/comm/environment/climat/greenhouse_monitoring.htm.

de Melo, J. and D. Tarr (1992): *A general equilibrium analysis of US foreign trade policy*. The MIT Press, Cambridge, MA.

Dervis, K., J. de Melo and S. Robinson (1981): A General equilibrium analysis of foreign exchange shortages in a developing economy. *Economic Journal*, **91**: 891-906.

Dixon, P. B., Parmenter, B. R. and Powell, A. A. (1984): The role of miniatures in computable general equilibrium modelling. *Economic Modelling*, **1**: 412-428.

Dixon, P. B. and Rimmer, M. T. (2002): *Dynamic General Equilibrium modeling for Forecasting and Policy*. North-Holland, Amsterdam.

Dolado, J. J., D. Gros and J. F. Jimeno (1998): La UEM y el mercado de trabajo en España: Costes y beneficios. Fundación Repsol, Madrid.

Dréze, J. and E. Malinvaud (1994): Growth and employment: the scope of a European initiative, *European Economic Review*, **38**: 489-504.

Fallon, P. and D. Verry (1988): *The Economics of Labour Markets*. Philip Allan, Hertfordshire, England.

Francois, J. F. and D. W. Roland-Holst (1997): Scale Economies and Imperfect Competition. In J. F. Francois and K. A. Reinert (eds.) *Applied Methods for Trade Policy Analysis: A Handbook*. Cambridge University Press, Cambridge, pp. 331-363.

García, I. and J. A. Molina (1998): Household labour supply with rationing in Spain. *Applied Economics*, **30**: 1557-1570.

Gómez-Plana, A. G. (1999): Efectos de cambios impositivos en un modelo de equilibrio general aplicado. *Revista Asturiana de Economía*, **15**: 23-42.

Gómez-Plana, A. G. (2001): Extensiones de la Matriz de Contabilidad Social de España. *Estadística Española*, **147**: 125-163.

Gørtz, M., J. V. Hansen and M. Larsen (1999): CO_2-skatter, dobbelt-dividende og konkurrence i energisektoren: Anvendelser af den danske AGL-model ECOSMEC (CO_2 taxes, double dividend and competition in the energy sector: Applications of the Danish CGE model ECOSMEC). Arbejdpapir 1999:1, Danish Economic Council.

Hamermesh, D. S. (1993): *Labor Demand*. Princeton University Press, Princeton.

Harberger, A. C. (1972): The Incidence of the Corporation Income Tax. *Journal of Political Economy*, **70**: 215-240.

Hertel, T. W. (ed.) (1997): *Global Trade Analysis. Modelling and applications*. Cambridge University Press, Cambridge.

Howe, H. (1975): Development of the extended linear expenditure system from simple saving assumptions. *European Economic Review*, **6**: 305-310.

Huergo, E. (1998): "Identificación del poder de Mercado: Estimaciones para la industria española". Investigaciones Económicas **22**: 69-91.

IEA (1993a): *Energy Statistics of OECD countries 1990-1991*. International Energy Agency, OECD, Paris.

IEA (1993b): *Energy Balances of OECD countries 1990-1991*. International Energy Agency, OECD, Paris.

Kemfert, C. and H. Welsch (2000): Energy-Capital-Labor Substitution and the Economic Effects of CO_2 Abatement: Evidence for Germany. *Journal of Policy Modeling*, **22**: 641-660.

Majocchi, A. (1996): Green Fiscal Reform and Employment: A Survey. *Environmental and Resource Economics*, **8**: 375-397.

Markusen, J. R. (1990): Micro-foundations of external economies. *Canadian Journal of Economics*, **23**: 495-508.

Mathiesen, L. (1985): Computation of economic equilibria by a sequence of linear complementary problems. *Mathematical Programming Study*, **23**: 144-162.

McConnel, C. R., S. L. Brue and D. Macpherson (1999): *Contemporary Labor Economics*. 5^{Th} edition. McGraw-Hill, Boston.

Mors, M. (1995): Employment, revenues and resource taxes: genuine link or spurious coalition?. *Int. J. Environment and Pollution*, **5**: 118-134.

OECD (1993): Energy Balances of OECD Countries 1990-1991, OECD, Paris.

Petrongolo, B., C. A. Pissarides (2001): Looking into the black box: A survey of the matching function. *Journal of Economic Literature*, **39**: 390-431.

Pissarides, C. A. (1998): The impact of employment tax cuts on unemployment and wages; The role of unemployment benefits and tax structure. *European Economic Review*, **42(1)**: 155-183.

Rutherford, T. F. (1999): Applied general equilibrium modeling with MPSGE as a GAMS subsystem: An overview of the modeling framework and syntax. *Computational Economics*, **14**: 1-46.

Rutherford, T. F. and S. Paltsev (2000): GTAP-Energy in GAMS: The Dataset and Static Model. Working Paper 00-02, Department of Economics, University of Colorado, Boulder.

Røed, K. and S. Strøm (2002): Progressive taxes and the labour market: Is the trade-off between equality and efficiency inevitable?. *Journal of Economic Surveys*, **16(1)**: 77-110.

Schöb, R. (2003): The Double Dividend Hypothesis of Environmental Taxes: A Survey, Working paper 60.2003, Fondazione Eni Enrico Mattei, Milano, http://www.feem.it/Feem/Pub/Publications/WPapers/default.htm

Toharia, L. (1996): "Empleo y paro en España: Evolución, situación y perspectivas", Ekonomiaz, **35:** 36-67.

Uriel, E., P. Beneito, F. J. Ferri and M. L. Moltó (1997): Matriz de Contabilidad Social de España 1990 (MCS-90). Instituto Nacional de Estadística, Madrid.

FIGURES AND TABLES

Table 1. Classification of sectors

	Sectors
1	Agriculture
2	Coal
3	Oil
4	Gas
5	Electricity
6	Water and other energy sources
7	Nonenergy minerals, chemicals
8	Metal and machinery
9	Other manufacturing
10	Construction
11	Commerce and hotel trade
12	Road transport
13	Other transport and communications
14	Finance and insurance
15	House renting
16	Other services

Table 2: The pure abatement effects, and the recycling effects of different schemes

	Table 2a: Pure abatement effects	Table 2b: Recycling effects;			
	% change from benchmark	% change from Case A			
	Case A	CASE B	CASE C	CASE D	CASE E
Unemployment rate skilled	-0,02	-0,15	0,01	0,15	-0,54
Unemployment rate unskilled	-0,03	-0,08	0,01	-0,22	0,09
Unemployment rate (agg)	-0,02	-0,1	0,01	-0,01	-0,23
Employment skilled	0,03	0,24	-0,02	-0,25	0,9
Employment unskilled	0,07	0,23	-0,01	0,58	-0,24
Employment (agg)	0,05	0,24		0,23	0,25
Labour supply skilled	0,03	0,23		-0,23	0,84
Labour supply unskilled	0,06	0,21		0,53	-0,21
Labour supply (agg)	0,05	0,22		0,22	0,21
Welfare	-0,59	0,37	0,4	0,36	0,37
market wage rate skileld	-1,61	1,77	0,41	0,38	3,6
market wage rate unskilled	-1,49	1,79	0,43	2,77	0,46
Capital rent	-1,46	0,16	0,46	0,12	0,2

Figure 1: Nesting structure for production[10]

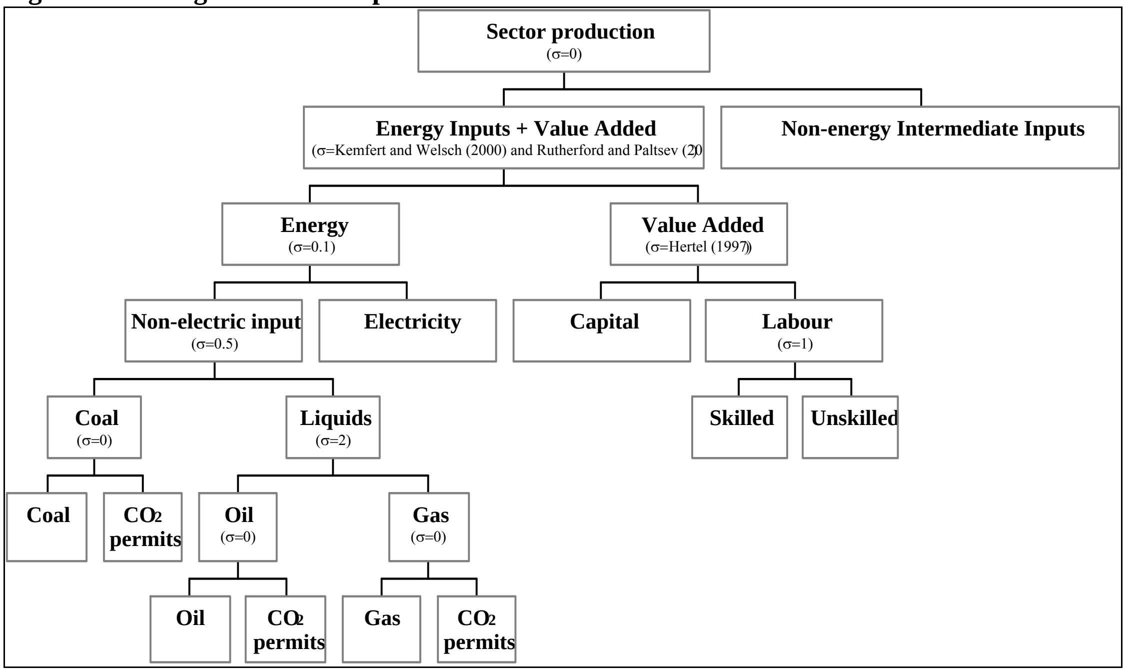
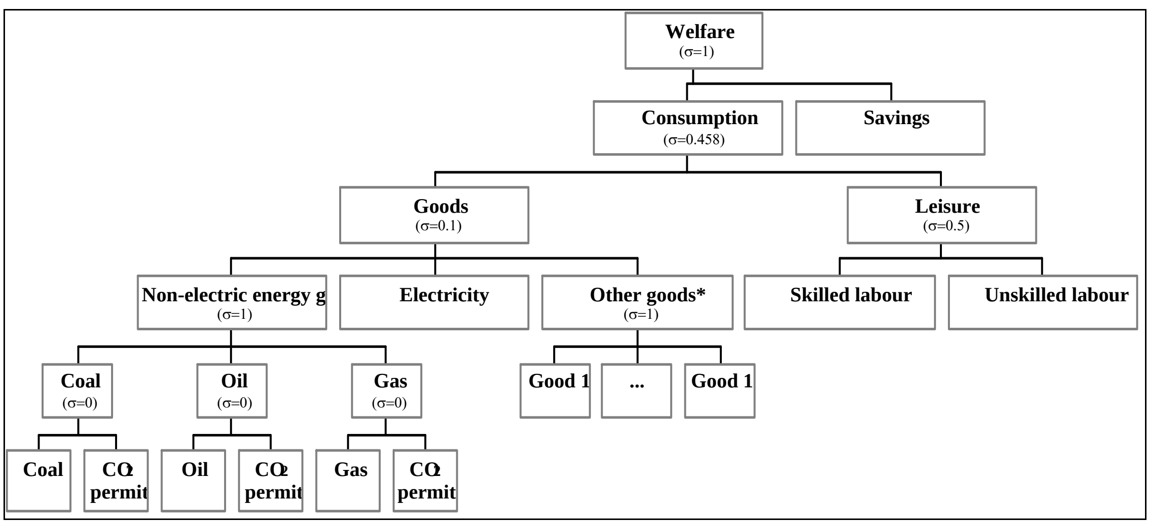


Figure 2: Nesting structure for consumption[11]



[10] The elasticity of substitution, σ, represents the substitution among components immediately below.
[11] The elasticity of substitution, σ, represents the substitution among components immediately below.

Figure 3: The Labour market loci (LL) and Trade balance loci (DD) in Case 0 (benchmark), Case A, Case B and Case C

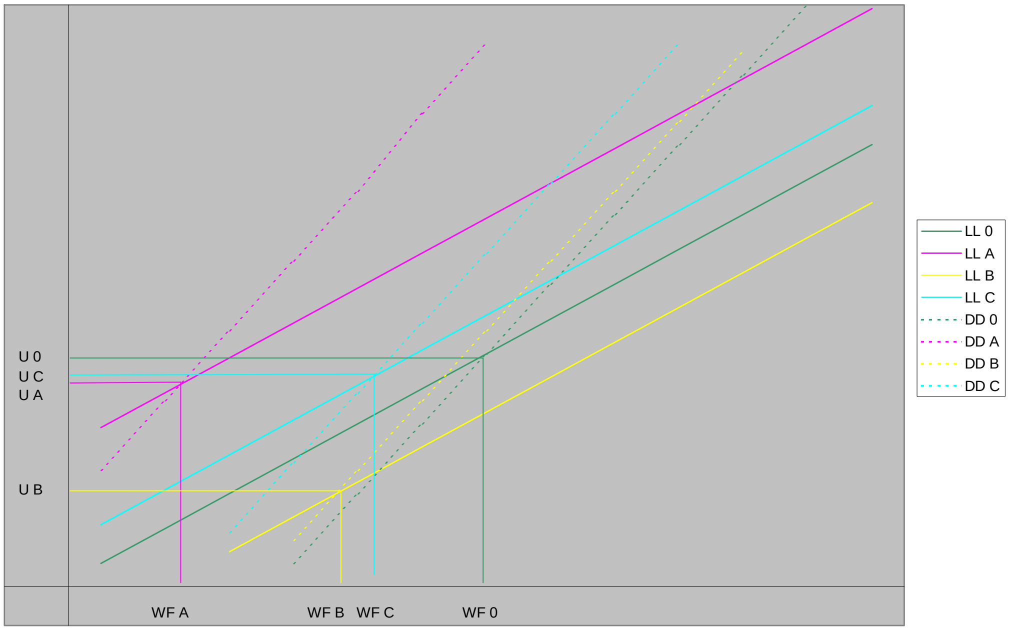
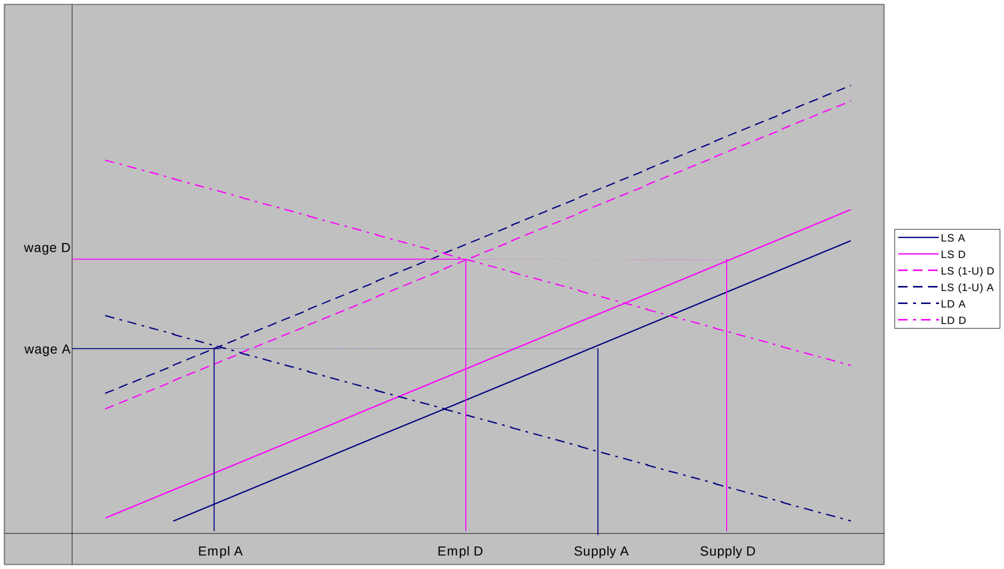
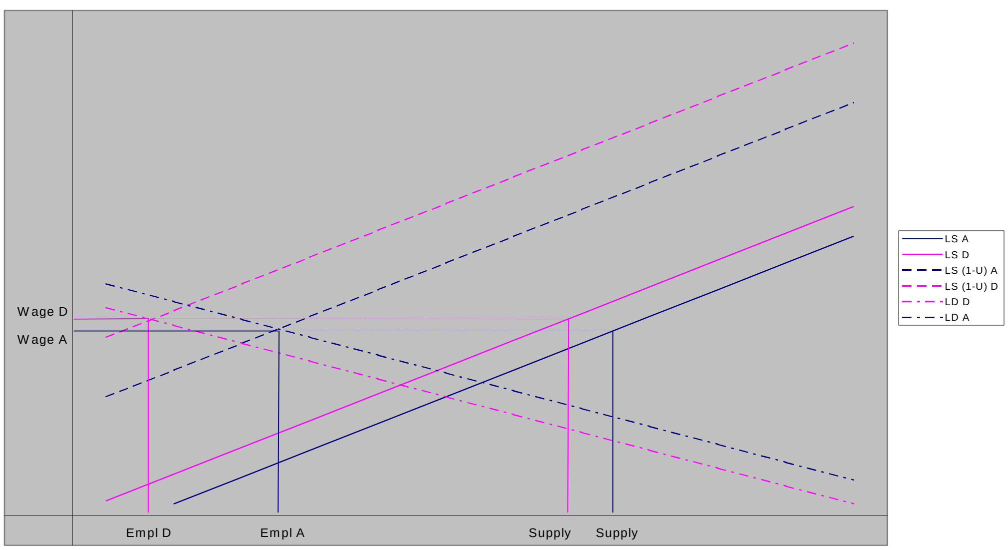


Figure 4: Effects of recycling through payroll tax for unskilled (Case D vs. Case A)

4A: Labour market for unskilled:



4B: Labour market for skilled:



APPENDIX 1: NOTATION

As a general rule, the notation in the model is as follows: endogenous variables are denoted by capital letters, exogenous variables by capital letters with a bar, and parameters by small Latin and Greek letters. There are *n* (*i,j=1,…,n=16*) production sectors, where good *n* is referred to the public sector and there are two subsets: *fuel* (representing coal, gas and oil) and *en* (representing electricity, coal, gas and oil).

Table A1: Endogenous variables

Symbol	**Definition**
A_i	Armington aggregate (total amount of goods supplied) of sector *I*
CARBON	Revenue from carbon permits
CF_i	Final domestic consumption of goods produced by sector *i*
$CO2^{C}_{fuel}$	CO_2 emissions from *fuel* combustion in final consumption
E_i	Number of firms in sector *I*
EXP_i	Exports of sector *I*
FC	Conversion factor of foreign currency into domestic currency
H^s, H^{us}	Inverse of the premium on reservation wages for skilled and unskilled labour
I_i	Investment (gross capital formation) in goods produced by sector *I*
II_{ij}	Intermediate inputs from sector *j* used by sector *i*
IMP_i	Imports from sector *I*
IT_i	Revenue from tariffs on imports from sector *i*
$MARKUP_i$	Price-cost margin in sector *I*
NIT_i	Revenue from net indirect taxes in sector *i*
O_i	Production of sector *i* sold in the domestic market
P_{sav}	Shadow price of savings
PA_i	Unit cost of the Armington aggregate of sector *i*
PCARB	Unit cost of an emission permit
$PDIST_i$	Unit cost of of the distributed production of sector *i*
PE_i	Unit cost of energy of sector *I*
$PEVA_i$	Unit cost of energy and value added of sector *i*
PINV	Unit cost of aggregate investment
PL_i	Unit cost of labour used in sector *i*
$PLIQ_i$	Unit cost of liquids of sector *I*
POC_i	Unit cost of the production of sector *i* sold in the domestic market. It includes the permit price carbon emission for sectors coal, oil and gas
PO_i	Unit cost of the production of sector *i* sold in the domestic market
$PNEL_i$	Unit cost of non-electric energy of sector *i*
PVA_i	Unit cost of primary factors of sector *I*
PX_i	Price of effective production of sector *i*
Q_c	Demand for aggregate consumption
Q_{cq}	Demand for aggregate consumption of goods
Q_{fuel}	Demand for consumption of *fuel*

Q_{en}	Demand for consumption of good *en*
Q_{ocg}	Demand for other consumption goods
Q_l	Demand for leisure
Q_l^s, Q_l^{us}	Leisure associated to skilled and unskilled labour
R	Capital rent
$SOCCE_i$	Revenue from social contributions payed by employers of sector *I*
$SOCCW_i$	Revenue from social contributions payed by employees of sector *i*
U^s, U^{us}	Unemployment rates of skilled and unskilled labour
W^s, W^{us}	Wages of skilled and unskilled labour
$W_0{}^s$, $W_0{}^{us}$	Reservation wages of skilled and unskilled labour
WF	Welfare
X_i	Effective production of sector *i*
Y_{RC}	Disposable income of the representative consumer
$\kappa_i{}^d$	Perceived elasticity of demand in sector *i*
Π_i^A	Unit profits for A_i (according to origin)
Π_i^{CET}	Unit profits for A_i (according to destination)
Π_i^X	Unit profits for X_i

Table A2: Exogenous variables and parameters

Symbol	**Definition**
$\overline{BALPUB}$	Balance of the public sector
$\overline{D}$	Trade balance surplus
$\overline{CF_n}$	Consumption of the public sector
$\overline{INVPUB}$	Investment of the public sector
$\overline{INVTOTAL}$	Total investment of the economy
$\overline{K_{RC}},\overline{K_G}$	Capital endowment for the representative consumer and public sector
$\overline{KF_i}$	Fixed requirements of capital in sector *I*
$\overline{L^s},\overline{L^{us}}$	Endowments of skilled and unskilled labour
$\overline{LF_i^s},\overline{LF_i^{us}}$	Fixed requirements of skilled and unskilled labour in sector *i*
$\overline{NTPS}$	Net transfers from the public sector, received by the representative consumer
$\overline{PFX}$	World prices
$\overline{Q_{sav}}$	Demand for savings
$\overline{SAVPUB}$	Savings of the public sector
$\overline{TOTCO2}$	Initial level of CO_2 emissions
$\overline{U^s},\overline{U^{us}}$	Unemployment rates of skilled and unskilled labour in the base year
$\overline{X_i}$	Effective production of sector *i* in the base year
$\overline{Y_G}$	Public sector income
$a1_i ,\ldots,a6_i$, $b1,b2$, $b3_i$, c_{0i}, c_{ji}, d_i, e_i, g_{fuel}, h_{fuel}	Share parameters
it_i	*Ad valorem* tariff rates in sector *I*
nit_i	*Ad valorem* indirect taxes rates in sector *I*
$soccw^s_i$, $soccw^{us}_i$	*Ad valorem* social contributions rates paid by employees in sector *I*
$socce^s_i$, $socce^{us}_i$	*Ad valorem* social contributions rates paid by employers in sector *I*
Ω_i	Conjectural variations parameter in sector *I*
$\alpha 1_i,\ldots,\alpha 6_i$, ζ_i	Scale parameters
ε_i	Elasticity of transformation in sector *I*
η_0,η_1	Externalities from labour supply and unemployment
θ	Factor of abatement
σ_i^A	Armington elasticity of substitution in sector *I*
σ^{CL}	Elasticity of substitution between consumption and leisure
σ_i^{ELK}	Elasticity of substitution between energy inputs, labour and capital in sector *I*
σ_i^{LK}	Elasticity of substitution between labour and capital in sector *I*
τ_i,τ_{sav}	Share parameters

APPENDIX 2: EQUATIONS

We present the complete set of equations included in the model. The general equilibrium model is solved as a mixed complementarity problem (see Mathiesen, 1985). Hence, it involves four sets of equations: zero profit conditions, market clearing equations in good and factor markets, budget constraints, and some additional constraints. The model core is a basic Arrow-Debreu model extended with some constraints and assumptions.

A2.1. Production

The base model presents increasing returns to scale due to some fixed costs, and a non-competitive pricing rule. Given that the upper nest is a Leontief function, the zero profit condition for each sector *i* is: *(i=1,…,16)*:

$$\Pi_i^X = PX_i - \frac{\left(R\overline{KF}_i + W^s\overline{LF_i^s} + W^{us}\overline{LF_i^{us}}\right)E_i}{X_i} - c_{0i}PEVA_i - \sum_{j=1}^{n(n\neq en)} c_{ji}PO_j = 0 \qquad \textbf{(A1)}$$

According to the nested structure, there is a sequence of CES nests that defines the unit cost for the composite of energy and value added ($PEVA_i$). This nested sequence is ($i=1,\ldots,16$):

$$PEVA_i = \frac{1}{\alpha 1_i}\left(a1_i^{\sigma_i^{ELK}} PE_i^{1-\sigma_i^{ELK}} + (1-a1_i)^{\sigma_i^{ELK}} PVA_i^{1-\sigma_i^{ELK}}\right)^{\frac{1}{1-\sigma_i^{ELK}}}$$

$$PVA_i = \frac{1}{\alpha 2_i}\left(a2_i^{\sigma_i^{LK}} PL_i^{1-\sigma_i^{LK}} + (1-a2_i)^{\sigma_i^{LK}} R^{1-\sigma_i^{LK}}\right)^{\frac{1}{1-\sigma_i^{LK}}}$$

$$PL_i = \frac{1}{\alpha 3_i}\left(\frac{W^s\left(1+socce_i^s+soccw_i^s\right)}{a3_i}\right)^{a3_i}\left(\frac{W^{us}\left(1+socce_i^{us}+soccw_i^{us}\right)}{1-a3_i}\right)^{1-a3_i}$$

$$PE_i = \frac{1}{\alpha 4_i}\left(a4_i^{0.1} PNEL_i^{1-0.1} + (1-a4_i)^{0.1} PO_{elec}^{1-0.1}\right)^{\frac{1}{1-0.1}}$$

$$PNEL_i = \frac{1}{\alpha 5_i}\left(a5_i^{0.5} POC_{coal}^{1-0.5} + (1-a5_i)^{0.5} PLIQ_i^{1-0.5}\right)^{\frac{1}{1-0.5}}$$

$$PLIQ_i = \frac{1}{\alpha 6_i}\left(a6_i^{2} POC_{oil}^{1-2} + (1-a6_i)^{2} POC_{gas}^{1-2}\right)^{\frac{1}{1-2}}$$

$$POC_{fuel} = g_{fuel}\,PO_{fuel} + \left(1-g_{fuel}\right)PCARB, \qquad fuel=coal,\ oil,\ gas$$

We assume that the domestic producers maximize profits and select the optimal mix of domestic production and imports. They also maximize profits when deciding the share that is going to be sold in the domestic market and the share that is going to be exported. Both facts entails two zero profits functions ($i=1,\ldots,16$):

$$\Pi_i^A = PA_i - \left(e_i^{\sigma_i^A}\left(PX_i(1+nit_i)\right)_i^{1-\sigma_i^A} + (1-e_i)^{\sigma_i^A}\left(\overline{PFX}FC(1+it_i)\right)^{1-\sigma_i^A}\right)^{\frac{1}{1-\sigma_i^A}} = 0 \qquad \textbf{(A2)}$$

$$\Pi_i^{CET} = PA_i - \frac{1}{\zeta_I}\left(d_i^{-\varepsilon_i} PO_i^{\varepsilon_i+1} + (1-d_i)^{-\varepsilon_i}\left(\overline{PFX}FC\right)^{\varepsilon_i+1}\right)^{\frac{1}{\varepsilon_i+1}} = 0 \qquad \textbf{(A3)}$$

The previous zero profit conditions are used to derive demand functions. If we apply Shepard's Lemma on cost functions, we get unitary derived demands.

Next we introduce the corresponding market clearing equations. The left-hand side represents the demands, and right-hand side are supplies for all the markets included in the foregoing zero profit conditions (*i,j=1,…,16*):

$$X_i\left(-\frac{\partial\Pi_i^X}{\partial PO_j}\right) = II_{ji} \qquad \textbf{(A4)}$$

$$\sum_{i=1}^{n} E_i\overline{KF_i} + \sum_{i=1}^{n} X_i\left(-\frac{\partial\Pi_i^X}{\partial R}\right) = \overline{K_{RC}} + \overline{K_G} \qquad \textbf{(A5)}$$

$$\sum_{i=1}^{n} E_i\overline{LF_i^s} + \sum_{i=1}^{n} X_i\left(-\frac{\partial\Pi_i^X}{\partial W^s}\right) = \left(\overline{L^s} - Q_l^s\right)\left(1-U^s\right) \qquad \textbf{(A6)}$$

$$\sum_{i=1}^{n} E_i\overline{LF_i^{us}} + \sum_{i=1}^{n} X_i\left(-\frac{\partial\Pi_i^X}{\partial W^{us}}\right) = \left(\overline{L^{us}} - Q_l^{us}\right)\left(1-U^{us}\right) \qquad \textbf{(A7)}$$

$$A_i\left(-\frac{\partial\Pi_i^A}{\partial PX_i}\right) = X_i \qquad \textbf{(A8)}$$

$$A_i\left(-\frac{\partial\Pi_i^A}{\partial FC_i}\right) = IMP_i \qquad \textbf{(A9)}$$

$$A_i\left(-\frac{\partial\Pi_i^{CET}}{\partial PO_i}\right) = O_i \qquad \textbf{(A10)}$$

$$A_i\left(-\frac{\partial\Pi_i^{CET}}{\partial FC_i}\right) = EXP_i \qquad \textbf{(A11)}$$

$$X_i + IMP_i = O_i + EXP_i \qquad \textbf{(A12)}$$

$$I_i + \sum_{j=1}^{n} II_{ij} + CF_i = O_i \qquad \textbf{(A13)}$$

The markup function to cover fixed costs is *(i=1,…,16)*:

$$MARKUP_i = \frac{PX_i - c_{0i}PEVA_i - \sum_{j=1}^{n(n\neq en)} c_{ji}PO_j}{PX_i} \qquad \textbf{(A14)}$$

Which corresponds to the Lerner index:

$$MARKUP_i = \frac{\Omega_i}{E_i \kappa_i^d} \tag{A15}$$

And:

$$\kappa_i^d = \sigma_i^A - \left(\sigma_i^A - 1\right) \frac{PX_i X_i}{\sum_{i=1}^{n} PX_i X_i} \tag{A16}$$

A2.2. Consumption

The final demand functions are derived from the maximization of the representative consumer's nested welfare function (see Figure 2):

$$WF = \left(Q_c\right)^{1-\tau_{sav}} \left(\overline{Q_{sav}}\right)^{\tau_{sav}} \tag{A17}$$

subject to the budget constraints:

$$Y_{RC} = W^s \left(\overline{L^s} - Q_l^s\right)\left(1 - U^s\right) + W^{us}\left(\overline{L^{us}} - Q_l^{us}\right)\left(1 - U^{us}\right) + R\overline{K_{RC}} + \overline{NTPS} \tag{A18}$$

$$Y_{RC} = P_{sav}\overline{Q_{sav}} + \sum_{i=1}^{n} PO_i CF_i + \sum_{fuel} PCARB\, CO2_{fuel}^C \tag{A19}$$

where the nests in the welfare function are defined by:

$$Q_c = \left(b1^{\sigma^{CL}} Q_{cg}^{1-\sigma^{CL}} + (1-b1)^{\sigma^{CL}} Q_l^{1-\sigma^{CL}}\right)^{\frac{1}{1-\sigma^{CL}}} \tag{A20}$$

$$Q_l = \left(b2^{0.5} Q_l^{s\,1-0.5} + (1-b2)^{0.5} Q_l^{us\,1-0.5}\right)^{\frac{1}{1-0.5}} \tag{A21}$$

$$Q_{cg} = \left(b3_{en}^{0.1} Q_{en}^{1-0.1} + b3_{elec}^{0.1} Q_{elec}^{1-0.1} + b3_{ocg}^{0.1} Q_{ocg}^{1-0.1}\right)^{\frac{1}{1-0.1}} \tag{A22}$$

$$Q_{en} = \left(Q_{coal}\right)^{\tau_{coal}} \left(Q_{oil}\right)^{\tau_{oil}} \left(Q_{gas}\right)^{\tau_{gas}} \tag{A23}$$

$$Q_{fuel} = \left(\frac{CF_{fuel}}{h_{fuel}}, \frac{CO2_{fuel}^C}{1-h_{fuel}}\right), \qquad fuel = coal, oil, gas \tag{A24}$$

$$Q_{ocg} = \prod_{i=1}^{n-1} CF_i^{\tau_i}\,, \qquad i \neq elec, coal, oil, gas \tag{A25}$$

The resolution of the maximization problem yields demand functions for savings ($\overline{Q_{sav}}$), leisure for skilled labour ($Q^s{}_l$), leisure for unskilled labour ($Q^{us}{}_l$), final demand (CF_i) and carbon permits demand ($CO2_{fuel}^C$) that enter in equations (A37), (A6), (A7), (A13) and (A31), respectively.

A2.3. Public sector

The role of the public sector is to set and collect taxes. The income of this sector is:

$$\overline{Y_G} = R\overline{K_G} + \sum_{i=1}^{n}(SOCCE_i + SOCCW_i) + \sum_{i=1}^{n}(NIT_i + IT_i) + CARBON - \overline{NTPS} \qquad \textbf{(A26)}$$

where the public revenue comes from:

$$SOCCE_i = socce_i W^s X_i\left(-\frac{\partial \Pi_i^X}{\partial W^s}\right) + socce_i W^{us} X_i\left(-\frac{\partial \Pi_i^X}{\partial W^{us}}\right) \qquad \textbf{(A27)}$$

$$SOCCW_i = soccw_i W^s X_i\left(-\frac{\partial \Pi_i^X}{\partial W^s}\right) + soccw_i W^{us} X_i\left(-\frac{\partial \Pi_i^X}{\partial W^{us}}\right) \qquad \textbf{(A28)}$$

$$NIT_i = PDIST_i A_i\left(-\frac{\partial \Pi_i^A}{\partial PDIST_i}\right) nit_i \qquad \textbf{(A29)}$$

$$IT_i = \overline{PFX}\, FC\, A_i\left(-\frac{\partial \Pi_i^A}{\partial FC_i}\right) it_i \qquad \textbf{(A30)}$$

Moreover, the public sector can control CO_2 emissions through emission permits, where emissions come from production and consumption activities. The public sector can constrain the total level of emissions ($\overline{TOTCO2}$) through a factor of abatement (θ), which is equal to 1 in the benchmark. For example, a reduction in CO_2 emissions (i.e., reduction in the number of permits) of 25% means that θ is equal to 0.75. The next equation represents this mechanism:

$$\theta\ \overline{TOTCO2} = \sum_{i=1}^{n} X_i\left(-\frac{\partial \Pi_i^X}{\partial PCARB}\right) + \sum_{i=1}^{n} CO2_{fuel}^{C}, \qquad fuel{=}carbon{,}oil{,}gas \qquad \textbf{(A31)}$$

The public revenue accruing from the auction of permits/carbon taxation is:

$$CARBON = \sum_{i=1}^{n} X_i\left(-\frac{\partial \Pi_i^X}{\partial PCARB}\right) PCARB + \sum_{fuel} CO2_{fuel}^{C}\, PCARB, \qquad fuel{=}carbon{,}oil{,}gas$$

(A32)

Due to the assumption of neutrality regarding public sector activity, the macro closure rules are:

$$\overline{BALPUB} = \overline{SAVPUB} - \overline{INVPUB} \qquad \textbf{(A33)}$$

$$\overline{CF_n} = \overline{Y_G} - \overline{SAVPUB} \qquad \textbf{(A34)}$$

A2.4. Investment, savings and foreign sector

The macro closures involve some other constraints related to investment (equation (A35)) and the savings in the open economy (equations (A36) and (A37)):

$$\sum_{i=1}^{n} PO_i I_i = PINV\,\overline{INVTOTAL} \qquad \textbf{(A35)}$$

$$\sum_{i=1}^{n} \overline{PFX}\ EXP_i - \sum_{i=1}^{n} \overline{PFX}\ IMP_i = \overline{D} \qquad \textbf{(A36)}$$

$$P_{sav}\overline{Q_{sav}} + \overline{SAVPUB} - PINV\ \overline{INVTOTAL} = \overline{D}\ FC \qquad \textbf{(A37)}$$

A2.5. Factor markets

The equilibrium in the capital market is represented by equation (A5). The market clearing conditions in labour markets are (A6) and (A7) with some restrictions related to the matching unemployment assumptions:

$$W^{s} = W_0^{s} \frac{1}{H^{s}} \qquad \textbf{(A38)}$$

$$W^{us} = W_0^{us} \frac{1}{H^{us}} \qquad \textbf{(A39)}$$

$$H^{s} = \left(1 - \overline{U^{s}}\right) \left(\frac{\sum_{i=1}^{n} X_i \left(-\frac{\partial \Pi_i^X}{\partial W^{s}} \right)}{\sum_{i=1}^{n} \overline{X_i} \left(-\frac{\partial \Pi_i^X}{\partial W^{s}} \right)} \right)^{\eta_0} \left(\frac{U^{s}}{\overline{\overline{U^{s}}}} \right)^{\eta_1} \qquad \textbf{(A40)}$$

$$H^{us} = \left(1 - \overline{U^{us}}\right) \left(\frac{\sum_{i=1}^{n} X_i \left(-\frac{\partial \Pi_i^X}{\partial W^{us}} \right)}{\sum_{i=1}^{n} \overline{X_i} \left(-\frac{\partial \Pi_i^X}{\partial W^{us}} \right)} \right)^{\eta_0} \left(\frac{U^{us}}{\overline{\overline{U^{us}}}} \right)^{\eta_1} \qquad \textbf{(A41)}$$

A2.6. Perfect competition

Assuming constant returns to scale (CRTS), the core of the model remains (production functions are defined in Figure 1). Nevertheless, some equations are replaced when the model is changed from the non-competitive version to the competitive one. The zero profit equation (A1') replaces equation (A1) *(i=1,…,16)*:

$$\Pi_i^X = PX_i - c_{0i} PEVA_i - \sum_{j=1}^{n(n \neq en)} c_{ji} PO_j = 0, \qquad i=1,\dots,16 \qquad \textbf{(A1')}$$

In the CRTS version, there are no fixed costs of primary factors, and we must replace market-clearing conditions (A5) to (A7) by:

$$\sum_{i=1}^{n} X_i \left(-\frac{\partial \Pi_i^X}{\partial R} \right) = \overline{K_{RC}} + \overline{K_G} \qquad \textbf{(A5')}$$

$$\sum_{i=1}^{n} X_i \left(-\frac{\partial \Pi_i^X}{\partial W^{s}} \right) = \left(\overline{L^{s}} - Q_l^{s} \right)\left(1 - U^{s}\right) \qquad \textbf{(A6')}$$

$$\sum_{i=1}^{n} X_i \left(-\frac{\partial \Pi_i^X}{\partial W^{us}} \right) = \left(\overline{L^{us}} - Q_l^{us} \right)\left(1 - U^{us}\right) \qquad \textbf{(A7')}$$

APPENDIX 3: CALIBRATION AND DATA

The model has been calibrated using the Spanish Social Accounting Matrix for 1990 MCS-90 developed in Uriel *et al*. (1997) and Gómez-Plana (2001). The matrix represents the benchmark equilibrium of the model. Calibration is made in three steps. In the first step, the matrix collects the quantities appearing in the equations, that means a first reference point in the isoquant of the calibrated function. In the second step, relative prices in 1990 fix the slope of the isoquant in that point. Since matrix data do not distinguish between prices and quantities, only showing values, we follow Harberger's (1972) assumption and choose the quantity units for goods and factors so that prices are unitary. The last step in the calibration uses elasticities, which show the curvature of the isoquant. To sum up, we have the slope and curvature for a point in each isoquant, and from there, all the unknown parameters are calibrated using Rutherford's (1999) method.

Elasticities pay a key role in this model due to the calibration method applied. Therefore a careful research for the benchmark values has been performed. The nested structure of the production technology (see Section 2.2) follows Rutherford and Paltsev’s (2000) CGE model, with some additional information (see Table A3): elasticities of substitution between labour and capital σ_i^{LK}, as well as Armington elasticities σ_i^{A} are taken from GTAP (Hertel, 1997). The available evidence shows quite different figures for elasticities of substitution between skilled and unskilled labour σ_i^{LL}, which may range from more than 5 to (small) negative values; see Hamermesh (1993), Chapter 3. The simulations have been performed using a “low” value of 1, which would agree with the recent estimates of Biscourp and Gianella (2001) for French manufacturing. Elasticities of substitution between energy and value added σ_i^{E-LK} for manufactures are taken from Kemfert and Welsch (2000). Finally, elasticities of transformation ε_I come from de Melo and Tarr (1992).

Table A3: Elasticities and Herfindahl indexes[12]

	SECTORS	σ_i^{LK}	σ_i^{A}	ε_i	σ_i^{E-LK}	$1/E_i$
1	Agriculture	0.56	2.2	3.9	0.5	0,00154
2	Coal	1.12	2.8	2.9	0.5	0,06716
3	Oil	1.12	2.8	2.9	0.5	0,32994
4	Gas	1.12	2.8	2.9	0.5	0,08997
5	Electricity	1.26	2.8	2.9	0.5	0,08997

[12] σ_i^{LK} and σ_i^{A}: Hertel (1997).
$_i$: de Melo and Tarr (1992).
σ_i^{E-LK}: Kemfert and Welsch (2000) and Rutherford and Paltsev (2000).
$1/E_I$: Elaborated from Bajo and Salas (1998).

6	Water and other energy sources	1.26	2.8	2.9	0.5	0,05095
7	Nonenergy minerals, chemicals	1.26	1.9	2.9	0.96	0,03533
8	Metal and machinery	1.26	2.8	2.9	0.88	0,04666
9	Other manufacturing	1.26	2.8	2.9	0.70	0,01404
10	Construction	1.40	1.9	0.7	0.5	0,00572
11	Commerce and hotel trade	1.68	1.9	0.7	0.5	0,01790
12	Road transport	1.68	1.9	0.7	0.5	0,00637
13	Other transport and communications	1.68	1.9	0.7	0.5	0,33973
14	Finance and insurance	1.26	1.9	0.7	0.5	0,03855
15	House renting	1.26	1.9	0.7	0.5	0,00127
16	Other services	1.26	1.9	0.7	0.5	0,00799

The elasticities of substitution for consumption also follow Rutherford and Paltsev (2000) with some additions and changes. The elasticity of substitution between leisure and consumption σ_h^{LQ} has been obtained using the procedure of Ballard *et al*. (1985), from the uncompensated elasticity of labour supply estimated in García and Molina (1998)[13]. A total of 40 hours worked per week, out of a potential 70, has been assumed. We have no data available on the elasticities of substitution between leisure for the skilled and leisure for the unskilled σ_h^{LEI}, so we assume they take a constant value across households of 0.5.

Table A4: Consumption of fuels[14]

	SECTORS	COAL	OIL	GAS	ELECTRICITY	TOTAL
1	Agriculture	0.01	1.37	0.03	0.3	1.72
2	Coal[15]	0.76	0	0	0	0.76
3	Oil[16]	0	4.20	0	0.17	4.37
4	Gas[17]	0.01	0.06	0.10[18]	0	0.17
5	Electricity[19]	14.11	2.18	0.27	1.96[20]	18.52
6	Water and other energy sources	0	0	0	0	0
7	Non-energy minerals, chemicals[21]	3.79	6.98	2.38	3.15	16.30
8	Metal and machinery[22]	0.09	0.31	0.35	0.63	1.38

[13] They estimate the elasticity of labour supply with respect to the own wage, for both men and women, from different functional forms. Since they find no evidence against the null hypothesis that these elasticities are zero, we use this value as starting point when computing σ_h^{LQ}.

[14] Units: Million metric tons of oil equivalent
Non-Energy Use is not included

[15] In table: Coal transformation + Own use

[16] In table: Petroleum Refineries (Crude oil – petroleum products) + Own use + Distribution losses

[17] In table: Gas Works

[18] In table: Own use + Distribution losses – gas produces (gas works)

[19] In table: Public electricity + CHP + Autoproducers of Electricity + CHP

[20] In table: Own use + Distribution losses

[21] In table: Iron and Steel + Non-ferrous Metals + Chemicals and Petrochemical + Non-metallic Minerals + Mining and Quarrying

[22] In table: Transport equipment + Machinery

9	Other manufacturing[23]	0.45	1.58	1.01	1.59	4.63
10	Construction	0	0.05	0	0.07	0.11
11	Commerce and hotel trade[24]	0.01	0.47	0.08	0.96	1.53
12	Road transport	0	18.05	0	0	18.05
13	Other transport & communications[25]	0	4.47	0	0.32	4.78
14	Finance and insurance[11]	0.00	0.26	0.05	0.52	0.83
15	House renting	0	0	0	0	0
16	Other services[11]	0.01	0.33	0.06	0.67	1.07
	Final consumption by households[26]	0.28	3.65	0.64	2.60	7.17

Source: Energy Balances of OECD Countries 1990-1991, OECD, Paris, 1993.

Benchmark emission levels are calibrated in the CGE model in the usual way (i.e., Bernstein *et al.*, 1999). IEA (1993a) provides data on consumption of fuels. We aggregate according to sectors and types of fuels displayed in our model (see Table A4). Then, we transform all variables in a common unity, EJ (displayed in Table A5), using Spanish specific conversion factors (see IEA, 1993b). Finally, we find CO_2 emissions at sectoral level by multiplying fuels consumption in EJ by emission coefficients. Emission coefficients, transforming from EJ to mt. of CO_2, for coal (0.024), gas (0.0137) and oil (0.0181) are taken from Rutherford and Paltsev (2000).

Table A5: Consumption of fuels in EJ

	SECTORS	COAL	OIL	GAS	TOTAL
1	Agriculture	0,0004168	0,0571016	0,0012504	0,0587688
2	Coal	0,0316768	0,0000000	0,0000000	0,0316768
3	Oil	0,0000000	0,1750560	0,0000000	0,1750560
4	Gas	0,0004168	0,0025008	0,0041680	0,0070856
5	Electricity	0,5881048	0,0908624	0,0112536	0,6902208
6	Water and other energy sources	0,0000000	0,0000000	0,0000000	0,0000000
7	Non-energy minerals, chemicals	0,1579672	0,2909264	0,0991984	0,5480920
8	Metal and machinery	0,0037512	0,0129208	0,0145880	0,0312600
9	Other manufacturing	0,0187560	0,0658544	0,0420968	0,1267072
10	Construction	0,0000000	0,0020840	0,0000000	0,0020840
11	Commerce and hotel trade	0,0004168	0,0195896	0,0033344	0,0233408
12	Road transport	0,0000000	0,7523240	0,0000000	0,7523240
13	Other transport & communications	0,0000000	0,1863096	0,0000000	0,1863096
14	Finance and insurance	0,0000000	0,0108368	0,0020840	0,0129208
15	House renting	0,0000000	0,0000000	0,0000000	0,0000000
16	Other service	0,0004168	0,0137544	0,0025008	0,0166720
	Final consumption by households	0,0116704	0,1521320	0,0266752	0,1904776
	Total	0,8135936	1,8322528	0,2071496	2,8529960

[23] In table: Food and Tobacco + Paper, Pulp and Printing + Wood and Wood Products + Textile and Leather + Non specified

[24] In table: Commerce and Public Services divided according to SAM weights based on production.

[25] In table: Air + Rail + Internal Navigation

[26] In table: Residental

The specification of the search costs requires values for two externalities. When it comes to matching functions, we have some evidence for Spain in Burda and Wyplosz (1994) and Castillo *et al*. (1998). The first study proves the no existence of constant returns to scale in the matching function and its estimations yields a value of 0.14 for η_0, and of 0.12 for η_1. On the other hand, Castillo *et al*. (1998) provide a value of 0.15 for η_0, and 0.85 for η_1. In the reference scenario, we use the values from the first study. However, the other values are used in a sensitivity analysis.

The data on imperfect competition are taken from Bajo and Salas (1998), who compute concentration indices using data on sales for more than two million Spanish firms, obtained from official VAT returns. Firms include all sectors, and not only manufactures as they are commonly estimated in literature. The indexes are displayed in Table A3.