Taxing International Emissions Trading

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Abstract

Most of the tradable permits regimes have ignored the role of emission allowances taxation, while the OECD and the European Union have emphasized the need for further investigation of the related efficiency and effectiveness consequences. The aim of our paper is to take a first step in this respect. We first illustrate a simple theoretical model featuring i representative competitive firms/countries. Firms take permits taxation as well as permits endowment as given and choose emissions and permits selling or buying behaviour accordingly. Our theoretical results show that explicitly accounting for permits taxation implies a distortion in the equilibrium price, as well as an impact on emissions. Also, the cost effectiveness property of emissions trading turns out to be violated. The specific features of such distortions are then investigated through a Computable General Equilibrium model, where several scenarios concerning taxes on net sellers' permits revenues and rebates on net buyers' permits costs are considered. The impact of each country's marginal abatement costs on price, emissions and tax revenues are assessed. A welfare analysis is also performed, suggesting that welfare losses related to taxation of emissions trading are minimized when no rebate is allowed for. More generally, the design of permits taxation is shown to be relevant in determining how gains and losses are distributed across countries.

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1. Introduction

In the context of international environmental negotiations, cap-and-trade systems are regarded as a cost-effective instrument to achieve abatement targets. Despite an extended literature has examined the functioning of a permits market in several respects, the tax treatment of revenues that arise in a permit trading market has not been fully addressed to date. A proper analysis of the tax treatment of permits is crucial for several reasons, including the need to avoid that permits transactions are undertaken exclusively for fiscal reasons; more generally, not accounting for permits revenues/costs taxation issues might lead to wrong conclusions in terms of their efficiency and effectiveness, as well as their impact on industry relocation decisions (see, for instance, Estrada *et al.*, 2009).

In this paper we aim at contributing to the literature on cap-and-trade regimes, by investigating how the tax treatment of emission allowances may affect the permits market in terms of their cost effectiveness, abatement decisions and welfare.

Most of the existing tradable permit systems have ignored the role of corporate and personal income tax and Valued Added Tax (VAT), implicitly assuming that tradable permits would be outside these fiscal regimes or that the impact of taxes would be neutral. Conversely, the fiscal treatment of emission permits turns out to be a crucial aspect of cap-and-trade regulations (Kane, 2009). As far as the European Union is concerned, for instance, the Directive 2003/87/EC establishing a Greenhouse Gas (GHG) allowance trading scheme within the Community makes no reference to the accounting and fiscal repercussions of the emission permits allocation or transfer. This is particularly surprising by considering that whilst the VAT is harmonized at EU level, the corporate income tax remains within the exclusive competence of each Member State. Differences between regulated countries can be associated to various aspects such as the accounting nature of emission rights, the burden of initial allocation and transfer, the deductible character of penalties resulting from non-fulfilment of the delivery obligation and the tax breaks for emission rights transfers.[1] As Fisher (2006) notes, the existence of tax differentials raise relevant design questions in emission control policies by affecting the allocation of abatement efforts within multinationals, across countries, and across firms.

In this work we move a step forward in investigating the effects of the tax treatment of emission allowances. The issue is first analysed theoretically; our theoretical results are than complemented by a numerical simulation analysis performed with a Computable General Equilibrium (CGE) model, allowing us to examine complex features of the international emissions trading system included in a general equilibrium framework.

In the analytical model, we consider i countries and i "representative" competitive firms, one in each country. Firms take emission permits taxation, as well as permits endowment as given, and choose consequently their emissions level and their selling or buying behaviour. According to our results, the permit taxation involves distortions both in the equilibrium permits price and in the distribution of the environmental target across countries. We show that taxing revenues from permits trading implies an upward shift in the equilibrium price, and the entity of such upward shift depends in a complex way on country characteristics (such as technology, tax burden, and so on).

Country specificities are explicitly considered in simulations carried out in the CGE model, which is based on a modified version of the GTAP-E model in order to evaluate the relative role of different structural features in explaining the impact of the tax treatment of emission permits, such as the consequences of asymmetries in tax rates or differences in marginal abatement costs.

In the last part of the analysis a cost effectiveness assessment is complemented with a welfare evaluation based on net sellers' and net buyers' equivalent variation.

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[1] Concerning the burden of initial allocation and transfer, for instance, the existence of substantial differences between countries in corporate tax rates can distort the proper functioning of emissions trading market, affecting both emission rights transfer operations and the location of emitting companies. Regarding the tax breaks for emission rights transfers, some countries may establish special fiscal regimes attracting in this way both activities related to emission permits trading and emitting industries.

From a theoretical point of view, the bulk of the existing contributions considering emissions trading jointly with tax issues deal with the pros and the cons of overlapping regulatory instruments (Böhringer *et al.*, 2008, Brechet and Peralta, 2007; Eichner and Pethig, 2009; Johnstone, 2003). Fischer (2006) investigates more specifically the interaction between multinational taxation and abatement activities under a IET scheme, mainly focusing on the impact of differentiated corporate income tax on abatement efforts by taking the equilibrium permits price as exogenous.

The only contributions that have explicitly addressed the impact of emissions trading revenues taxation are Kane (2009) and Yale (2008). The former provides a descriptive analysis of different aspects of this issue, where the main finding is that the proper tax treatment of a permits market should be considered according to the specific regulatory goal of minimizing abatement costs.

The latter examines theoretically the extent to which income taxation interferes with cap-and-trade environmental regulation, reaching two opposite conclusions according to the time horizon under scrutiny. Within a single tax period, taxing returns from permits does not distort firms' choices at the margin between using and selling permits or between buying permits and abating. At the opposite, taxes may distort firms' decisions regarding whether and to what extent they save permits for future use (permit banking). This is particularly true when permits are provided for free and their value is excluded from taxable income (holders with a zero basis in their permits). In this case, permits price will rise and the tax exemption is capitalized into the price of permits. Accordingly, tax rules can modify the relative costs of abatement in present and future periods by affecting the cost-effective allocation of emission allowances.

In the present work we specifically depart from Fischer (2006) and Yale (2006), but we model permits taxation in a more realistic way, showing how emission trading taxation leads to distortions by affecting the equilibrium outcome in the permits market, where permits price as well as emissions abatement decisions are taken endogenously.

Finally, our paper is somewhat linked to very recent works that evaluate emissions trading performance and design using general equilibrium modelling strategies as Böhringer *et al.* (2011) and Carbone *et al.* (2009).

The rest of the paper is organized as follows: Section 2 presents the theoretical model while Section 3 provides some details on the CGE model used for numerical simulations. Section 4 provides results from simulations design, and in Section 5 we provide some specific comments on welfare effects. Section 6 concludes.

2. The theoretical model

We consider a stylized model representing a set of I countries, indexed by $i = 1,...,I$. In each country there are a large number of atomistic identical firms; we can therefore assume that each country features one representative firm, labelled as firm i ($i = 1,\ldots,I$). Each firm generates polluting emissions x_i. Firm *i*'s benefits from pollution, $B_i(x_i)$, are assumed to be increasing and strictly concave in emissions, i.e. $B_i^{'}(x_i) > 0$ and $B_i^{''}(x_i) < 0$. The shape of $B_i(x_i)$ synthesized the effect related to each firm/country's industrial and technological features.

Each firm i receives an exogenous amount of emission permits, e_i, that can be traded on a perfectly competitive international market. Given the after-trade price p arising in the permits market, each firm chooses the level x_i^* maximizing the net benefits from pollution, defined as

$$\Pi_i = B_i(x_i) - p(1 - t_i)(x_i - e_i),$$

where t_i is the tax rate (rebate) on revenues (costs) generated by $(x_i - e_i)$, i.e. the amount of permits sold (when $x_i < e_i$) or bought (when $x_i > e_i$). Notice that we focus on specific permits trading taxation and not (as for example in Fischer 2006) on corporate or other kinds of taxation hitting the whole firm income.[2]

The first order condition of the firm's maximization problem is

$$B_i^{'}(x_i) - p(1 - t_i) = 0 \tag{1}$$

which implies:

$$\frac{B_i^{'}(x_i)}{(1 - t_i)} = p$$

This condition suggests that, whenever $t_i \neq t_j$ ($i, j = 1,\ldots,I$; and $i \neq j$) the taxation (rebate) of revenues (costs) arising from permits trading generates a violation of the cost effectiveness condition (i.e. $B_i^{'}(x_i) = B_j^{'}(x_j)\ \forall i, j = 1,\ldots,I$). Though expected, this result deserves some further considerations. Indeed, as Kane (2009) underlines, it is not obvious that cost effectiveness continues to hold when permits taxation is in place. From (1) we provide a simple but rigorous proof of such conjecture.

By totally differentiating (1) we get:

[2] Example under this respect could be application or exemption from VAT, or differentiated income taxation.

$$B_i''(x_i)dx_i - dp(1-t_i) + p\,dt_i = 0$$

which implies the following comparative statics results:

$$\frac{dx_i}{dp} = \frac{(1-t_i)}{B_i''(x_i)} < 0 \tag{2}$$

and

$$\frac{dx_i}{dt_i} = \frac{p}{B_i''(x_i)} > 0\,. \tag{3}$$

The signs of (2) and (3) define how the level of x_i changes when, for a given level of t_i, p increases and when, for a given level of p, t_i increases, respectively. Both the results can be easily explained: when p increases the net benefit of polluting decreases because to buy (sell) permits becomes more expensive (remunerative); on the other hand, $\frac{dx_i}{dt_i} > 0$ because the net cost of a permit, for any given permits price, is lowered by taxation, thus reducing the opportunity cost of emissions. From a deeper analysis of (2) and (3) we can observe the following:

Remark 1. *The reactivity of x_i w.r.t. p decreases with t_i and with the concavity of $B_i(x_i)$, while the reactivity of x_i w.r.t. t_i increases with p and decreases with the concavity of $B_i(x_i)$.*

As it is reasonable, a country where marginal benefits from emissions decrease more rapidly with emissions themselves (due, for example, to a mature technology) will *ceteris paribus* react in a slower way to changes in the permits price and/or in the tax rate. On the other hand, a country featuring a lighter tax burden will react more rapidly to changes in price. From Remark 1, we could expect that tax and technological features would play a crucial role in affecting the effectiveness and efficiency of a cap and trade program.

The equilibrium on the permits market is defined by the following condition:

$$\sum_{i\in I} x_i(p, t_i) = \sum_{i\in I} e_i\,. \tag{4}$$

Totally differentiating (4), we get

$$\sum_{i\in I}\frac{\partial x_i}{\partial p}dp+\sum_{i\in I}\frac{\partial x_i}{\partial t_i}dt_i=0.$$

If we assume that $dt_j = 0 \ \forall j = 1,...,I$, $j \neq i$, we can rewrite the total differential as

$$\sum_{i\in I}\frac{\partial x_i}{\partial p}dp+\frac{\partial x_i}{\partial t_i}dt_i=0,$$

so that the equilibrium price increases with tax rates of any country *i*, that is

$$\frac{dp^*}{dt_i}=-\frac{\dfrac{\partial x_i}{\partial t_i}}{\sum_{i\in I}\dfrac{\partial x_i}{\partial p}}>0. \tag{5}$$

We can then derive the following observation:

Remark 2. *The reactivity of p w.r.t.* t_i *increases with* $\frac{\partial x_i}{\partial t_i}$ *and decreases with* $\sum_{i\in I}\frac{\partial x_i}{\partial p}$.

Since the intensity of both $\frac{\partial x_i}{\partial t_i}$ ($\forall i \in I$) and $\frac{\partial x_i}{\partial p}$ depend on the concavity of $B_i(x_i)$, Remark 2 suggests that also the reactivity of p w.r.t. t_i depends on the concavity of the benefits functions in all involved countries/firms. However, the overall effect of the concavity of $B_i(x_i)$ (or loosely speaking, the effect of industrial characteristics of country *i*) is indeterminate in this theoretical framework, unless some *ad hoc* specifications are introduced on the functional form of $B_i(x_i)$. Indeed, a change in $B_i''(x_i)$ for some $i \in I$ affects the absolute values of both $\frac{\partial x_i}{\partial t_i}$ at the numerator and $\sum_{i\in I}\frac{\partial x_i}{\partial p}$ at the denominator.

We now turn to the overall effect of permits taxation. Eq. (3) tells us that there exists a positive direct effect. Nonetheless, there is also an indirect effect passing through the equilibrium price of permits. By equations (2) and (5) we know that an increase in t_i implies an increase in p^* which, in turn, implies a reduction of x_i. The overall impact can then be rewritten as:

$$\frac{dx_i^*}{dt_i} = \frac{\partial x_i^*}{\partial t_i} + \frac{\partial x_i^*}{\partial p^*}\frac{dp^*}{dt_i}$$

where the first addendum on the right hand side is the direct effect, while the second addendum is the indirect effect, driven by the permits price in equilibrium. After substituting from (3), (2) and (5), we can rewrite the overall effect of t_i on x_i^* as follows:

$$\frac{dx_i^*}{dt_i} = -\frac{p}{B_i''(x_i)}\left(1 - \frac{\frac{(1-t_i)}{B_i''(x_i)}}{\sum_{i\in I}\frac{(1-t_i)}{B_i''(x_i)}}\right) > 0. \tag{6}$$

We can conclude from (6) that an increase in the tax rate in any country *i* increases equilibrium emissions in the same country. In other words, the positive direct effect always dominates the negative indirect (or equilibrium) effect.

By looking at the effect of a country taxation on emissions produced by another country, we can also observe from (5) that there is a negative relation between the emissions level of any country $j \neq i$ w.r.t. the tax rate imposed by the *i-th* country:

$$\frac{dx_j}{dt_i} = \frac{\partial x_j}{\partial p^*}\frac{\partial p^*}{\partial t_i} < 0 \tag{7}$$

since $\frac{\partial x_j}{\partial p^*} < 0$ and $\frac{\partial p^*}{\partial t_i} > 0$.

The impact of changes in t_i can be summed up as follows.

Remark 3. *An increase in t_i in any country $i \in I$, ceteris paribus, generates an increase in emissions (and permits demand) in country i and a decrease in emissions (and permits demand) in all other countries.*

When we move to the impact of changes in tax rates in several (i.e. more than one) countries, we may observe more complex effects. Instead of resorting to specific functional forms - that could be an option suffering from some degree of arbitrariness - we examine how the international permits' price reacts to variations in the tax regimes of different countries through the CGE simulations where variables are calibrated in a realistic way.

It is crucial at this stage to underline that the distortion in equilibrium price and the consequent reallocation of emissions across countries generate welfare losses, by raising compliance costs given the overall abatement targets. As a consequence, taxation of emissions trading must be carefully evaluated by accounting for the possible related benefits in terms of collected public funds. Turning to the tax revenue, defined as

$$R_i = t_i p(e_i - x_i),$$

we get the following

$$\frac{\partial R_i}{\partial t_i} = \left(p + \frac{dp^*}{dt_i} t_i \right)(e_i - x_i) - t_i p \frac{dx_i}{dt_i} \tag{8}$$

which allows us to state that

Remark 4. *If country i is a net seller (i.e. $x_i < e_i$), its revenue increases if* $\left(p + \frac{dp^*}{dt_i} t_i \right)(e_i - x_i) > t_i p \frac{dx_i}{dt_i}$ *while, if country i is a net buyer (i.e. $x_i > e_i$), its revenue always decreases (i.e. the rebate increases) with the tax rate.*

In other words, when a country is a net seller of permits, the revenue increases if the impact of a change in the tax rate on the tax base (i.e. emissions) is sufficiently small and/or the change in unit tax revenue is sufficiently large.

It should be noted that there is also a tax related spillover, indeed

$$\frac{\partial R_j}{\partial t_i} = t_j \left[(e_j - x_j) \frac{dp^*}{dt_i} - p \frac{dx_j}{dt_i} \right] \tag{9}$$

implying that

Remark 5. *The revenue in country j always increases with t_i if country j is a net seller, while if country j is a net buyer, its revenue decreases (i.e. the rebate increases) if* $\left(e_j - x_j\right)\frac{dp^*}{dt_i} > p\frac{dx_j}{dt_i}$.

According to our theoretical results, the impact of permits taxation strongly depends on specific tax levels. In particular, when net sellers levy heterogeneous taxation, the abatement and efficiency impacts change widely in relation to which country introduces a higher or lower-than-average domestic tax rate. Concerning net buyers, they may introduce full or partial rebates (defiscalization) of permits acquisition costs, in order to compensate for the tax rate transferred on the sale price by sellers.

Let us graphically exemplify how the permits market is affected by taxation. Let us focus on a two countries/two representative firms economy and assume that marginal abatement costs are homogenous among countries, corresponding to the case where $B''(x_i) = \overline{B}'', \forall i$. In this case, the marginal abatement cost curve (bottom side of Figure 1) is the same for the two countries, that we label as A and B ($MAC_{A,B}$). The two countries differ in their abatement commitment, that we hypothesize as relatively higher for B (C_B) than for A (C_A). As a result, in the absence of emissions trading, country A should introduce a carbon tax ($CTax_A = P_A$) which would be larger than the corresponding one in country B ($CTax_B = P_B$); permits trade incentives would therefore arise.

In a two countries model, the permits quantity demanded by B is by construction equal to the supply provided by A. Hence, the market is confined to the quantities associated to the range P_A-P_B in the bottom part of the graph. The equilibrium price (P_E) corresponds to the point on the $MAC_{A,B}$ where country A decides to reduce emissions more than its target until the domestic abatement costs of the two countries are equalized. In equilibrium, by definition, permits sold by one country equal permits bought by the other. We can therefore represent the permits market in a standard demand/supply graph, as in the top of Figure 1, where the exchanged equilibrium quantity is $0Q_E = C_AR_{A,B} = R_{A,B}C_B$.

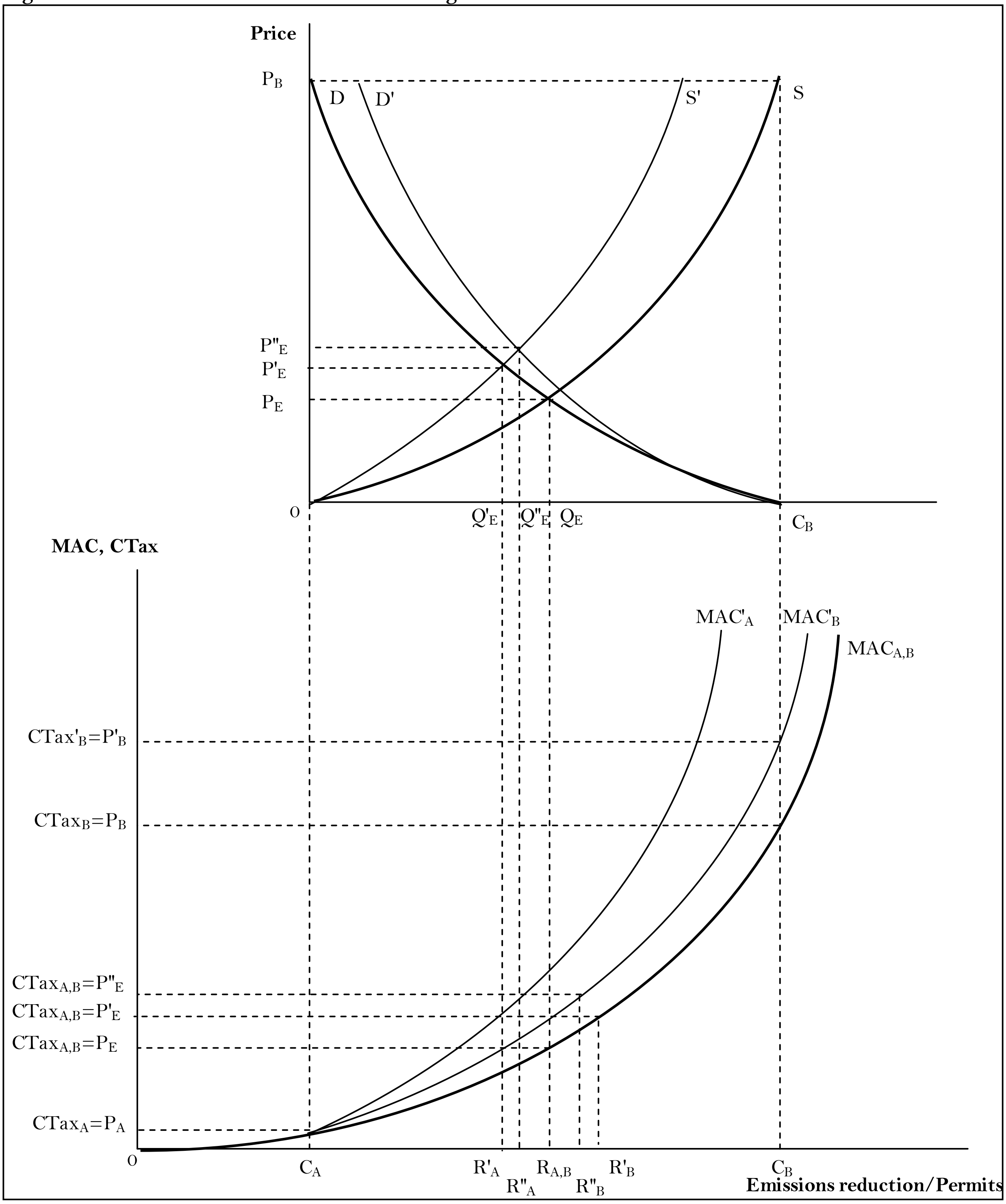
Suppose now that country A (the net seller) introduces a tax on permits revenue, while no rebate is allowed in country B. Country B stays on its previous $MAC_{A,B}$ while country A's MAC shifts leftward to MAC'_A (bottom of Figure 1);[3] this reduces the propensity to sell permits and therefore implies a leftward shift also in the supply curve (top of Figure 1). As a result, the equilibrium price increases (P'_E) and the exchanged quantity decreases ($C_AR'_A = R'_BC_B = Q'_E$).

Let us now assume that the buyer adopts a rebate. The new country B MAC would be MAC'_B resulting in a new demand curve (D'). As it clearly emerges from Figure 1, if a rebate is also

[3] Clearly MAC'_A differs from MAC_A only when permits are sold, i.e. on the right of level C_A in the bottom part of Figure 1.

accounted for, the price increases further with respect to the no rebate case (P''_E), while the amount of permits exchanged is closer to the no tax/no rebate case ($C_AR''_A=R''_BC_B= Q''_E$). In the extreme case where full fiscal harmonization is considered, the MAC'_B will coincide with the new MAC'_A.

Figure 1- Permits taxation in the case of homogeneous abatement costs



This would result in a net equilibrium price increase of the same magnitude of the tax rate, so that the after tax price and the quantity exchanged in equilibrium would not change with respect to the no tax case. Of course, this latter conclusion only holds due to the assumed (identical) shapes of the original (before the tax) MAC curves.

As it clearly emerges, asymmetries across countries in terms of technology, taxation and endowment affect the market for permits in a non straightforward way. Some general results could be obtained through our theoretical analysis, while using simulation tools, we will introduce some elements of realism, in order to achieve a deeper understanding of the involved mechanics and impacts also on a broader welfare dimension.

3. The CGE model for numerical simulations

In this paper we rely on the CGE GTAP-E model as an energy-environmental version of the standard GTAP model specifically designed to simulate policies in the contest of carbon emissions mitigation. It includes an explicit treatment of energy demand, inter-factor and inter-fuel substitution, carbon dioxide emissions accounting, as well as climate policies in terms of both domestic actions as carbon taxes, and flexible mechanisms as emissions trading (Burniaux and Truong, 2002; Mc Dougall and Golub, 2007).

Emissions trading is modelled defining bloc-level emissions and quotas assuming that only regulated countries can exchange permits in an international market. By defining exogenously abatement targets for each regulated country, it is possible to compute a carbon tax value endogenously, so that each country meets its commitments at the lowest domestic cost. When emissions trading is allowed, carbon tax represents the marginal cost of abatement equalized among all countries that participate to IET and at the equilibrium it coincides with the unique permits price.

Each country is characterized by a specific abatement cost function. On this basis - and considered its abatement target - the country becomes a net seller (buyer) respectively if the permit price is higher (lower) than the domestic abatement cost. The different abatement choices determine a unique equilibrium price of traded permits.

Considering the GTAP-E formulation concerning how carbon tax acts in reducing CO_2 emissions, in the standard version emission permits are not subject to taxation. Hence a specific modification to the model equations is required. While the theoretical model assumes that each country is the only agent deciding to abate more or less than its own target, and consequently selling or buying permits on the carbon market, in our CGE model abatement decisions are taken by private agents, namely firms and consumers. The amounts of abated emissions by private agents are then summed up and compared with the emission target at the national level. In order to translate private agents' decisions into the national abatement level, in this GTAP-E version the emission permits are taxed acting directly in the demand price function.[4] The carbon equilibrium price (nominal carbon tax given by the international market) faced by agents is augmented by an *ad valorem* permits tax/rebate rate, thus influencing the fossil fuels consumption behaviours of each economic agent. More precisely, the tax/rebate rate introduced into the GTAP-E model is uniform among economic sectors and differentiated between countries, allowing to simulate the effects related to homogeneous or heterogeneous rates.

In this paper, according to Antimiani *et al.* (2011), two major changes in the standard GTAP-E version are also introduced, enhancing the robustness of simulation results.[5]

First of all, we adopt the updated GTAP Database version 7.1 (base year 2004) as well as the latest version of the combustion-based CO_2 emissions data provided by Lee (2008) for all GTAP sectors and regions.

Second, some elasticity parameters in the energy nests have been replaced with those proposed by Beckman and Hertel (2010) for the substitution elasticity between the capital-energy composite and the other endowments, as well as for the Armington elasticities according to Hertel *et al.* (2007).[6]

The model settings include an aggregation of 21 sectors and 21 regions (Table A1 in the Appendix). Concerning regional aggregation, we consider as an ideal case a complete Kyoto Protocol environment, with 11 regulated countries/regions featuring country-specific CO_2 reduction commitments by 2012, where regional aggregation follows a simple criterion based on differences in abatement targets. Insofar, EU is taken as a single region, since its bargaining power has been exploited by obtaining a single abatement target (-8% with respect to 1990 emission levels), while for instance Croatia and Switzerland are treated separately, since they have negotiated two distinguished emission targets.[7]

As far as sectoral aggregation is concerned, we singled out energy sectors such as coal, crude oil, gas, refined oil products and electricity as well as other energy intensive sectors (cement, paper, steel and aluminium) since they are candidates as the main sources of production

[4] More in detail, the taxation on revenues from the emission permits' sale is modelled as affecting directly the emission permits price, and the same approach is adopted concerning the defiscalization of the costs related to emission permits' purchase.

[5] Emissions in our version could not account for all other GHG emissions since they relate only to fossil fuels combustion, thus providing a lower bound estimate of the abatement targets. The underestimation is quite homogeneous across regions and sectors with the exceptions of agriculture and chemicals sectors.

[6] For a comprehensive discussion about substitution elasticities in the energy sector, see Koetse *et al.* (2008), Okagawa and Ban (2008), while Panagarya *et al.* (2001) and Welsch (2008) discuss the role of import demand elasticities in international trade.

[7] Considering the Rest of the World, we singled out the major emerging economies, such as Brazil, China, India, Mexico, and South Africa. Nonetheless, in our simulations we are not interested in investigating the effects on non regulated countries, since the IET mechanism is allowed to regulated countries only.

reallocation, and other manufacturing non-energy intensive sectors as described by the IEA Energy Balances.

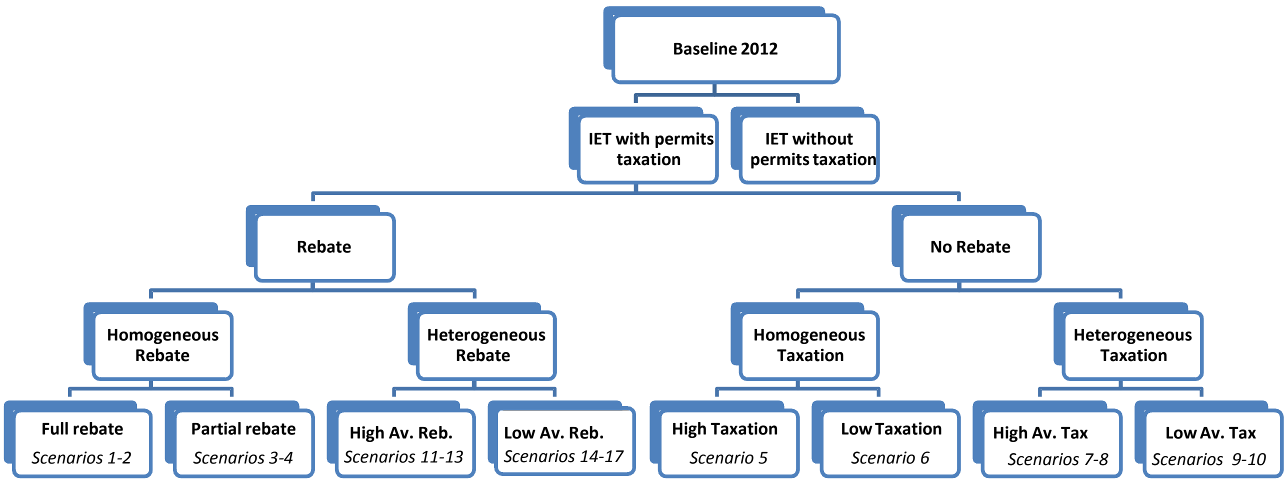
Finally, in order to compare economic and environmental effects of abatement decisions consistent with our ideal Kyoto environment, a 2012 baseline has been constructed starting from the GTAP 7.1 database relying on year 2004 data. To this purpose, we have considered a business as usual scenario for emissions data considering slow adoption of clean technologies and economic projections to 2012 accounting for International Monetary Fund and the World Bank information over effective growth rates after the financial and economic crisis.

As a final remark, we have also accounted for potential distortions arising when transition economies are allowed to sell permits in the carbon market. The huge potential supply by these countries would produce substantial distortions, partially invalidating the role of a IET scheme. Such uncertainties may be included in the so-called "hot air" debate, which also addresses the role of the other flexible mechanisms required by the Protocol (World Bank, 2010). In order to reduce potential market failures coming from this feature, we have adopted a partial adjustment to emission targets for Belarus and Former Soviet Union (FSU). For these specific countries, the emissions level by year 2012 has been taken as the reference to which the 0% target scheduled in the Protocol should be applied, rather than the usual 1990 period, reducing substantially their potential permits supply.

4. Simulations results

Since in a CGE approach results represent changes with respect to a baseline scenario, it is necessary to have a benchmark to compare with, thus we propose several scenarios following the theoretical model step by step (Figure 2).

Figure 2- Diagram of simulated scenarios



The baseline scenario simulates a IET system without taxation of carbon permits (hereafter referred as IET no Tax). This scenario represents the baseline in order to assess the relative impact of different options for fiscal treatment of emission permits revenues with respect to a no tax situation and allows to distinguish countries as net sellers or net buyers.

Starting from this benchmark, from the first set of scenarios (Table 1) it is possible to assess the impact of the introduction of a tax rate on emission permits revenues with respect to the IET no Tax case. In particular, we test the overall effects on the permits equilibrium price as well as on emission abatement decisions when different homogeneous tax and rebate rates are implemented (scenarios 1-2). We then assess the effects related to the magnitude of the gap between the tax and rebate rates when tax rates are at the maximum level and partial rebate rates are introduced (scenarios 3-4). In this case, the gap depends only on the net buyers' decisions concerning the fiscal treatment of emission permits' purchase costs. These simulations are related to the partial equilibrium analysis addressed by Figure 1, allowing to disentangle the effects of permits fiscal treatment on the final equilibrium price and on the market dimension (Remarks 1 and 2). Following this line of reasoning, we also examine the case when the gap between the tax and rebate rates depends only on the decisions taken by the net sellers, when no rebates are introduced (scenarios 5-6). By taking $t_i \equiv \bar{t}$, we can single out the specific impact of technological features, summed up by $B''(x_i)$, on equilibrium price and permits quantities. All these simulations allow considering the direct and indirect effect predicted by Remark 1 simultaneously.

Table 1- Alternative homogeneous tax and rebate rates

	Rebate				No rebate	
	Full		Partial		Homogeneous Tax	
IET Countries	(1)	(2)	(3)	(4)	(5)	(6)
Net sellers						
European Union	15.0%	35.0%	35.0%	35.0%	35.0%	15.0%
Former Soviet Union	15.0%	35.0%	35.0%	35.0%	35.0%	15.0%
Belarus	15.0%	35.0%	35.0%	35.0%	35.0%	15.0%
Switzerland	15.0%	35.0%	35.0%	35.0%	35.0%	15.0%
Net buyers						
United States	15.0%	35.0%	25.0%	15.0%	0.0%	0.0%
Canada	15.0%	35.0%	25.0%	15.0%	0.0%	0.0%
Australia	15.0%	35.0%	25.0%	15.0%	0.0%	0.0%
New Zealand	15.0%	35.0%	25.0%	15.0%	0.0%	0.0%
Japan	15.0%	35.0%	25.0%	15.0%	0.0%	0.0%
Croatia	15.0%	35.0%	25.0%	15.0%	0.0%	0.0%
Norway	15.0%	35.0%	25.0%	15.0%	0.0%	0.0%
Average tax rate $(\bar{t}_{tax})$	*15.0%*	*35.0%*	*35.0%*	*35.0%*	*35.0%*	*15.0%*
Average rebate rate $(\bar{t}_{rebate})$	*15.0%*	*35.0%*	*25.0%*	*15.0%*	*0.0%*	*0.0%*

It is worth noting that all tax and rebate rates are taken in the range of 15%-35%, as a purely exemplificative exercise.[8] Since the tax and rebate rates act as an *ad valorem* on the equilibrium

[8] The range adopted in simulations design has been taken in line with the corporate tax rates reported by the OECD for the most recent year (http://www.oecd.org/document/60/0,3746,en_2649_34897_1942460_1_1_1_1,00.html).

price, when taxation levels are homogeneous, the average tax/rebate rate corresponds to a simple mean of the nominal tax/rebate rates applied into abating countries. On the contrary, when tax/rebate rates are heterogeneous, the average tax/rebate rate corresponds to a weighted average of the nominal tax/rebate revenues, where weights are given by the net permits value at the equilibrium market price, formally defined as

$$\bar{t} = \frac{\sum_{i \in I} \left[p^* t_i \left(e^*_i - x_i \right) \right]}{\sum_{i \in I} \left[p^* \left(e^*_i - x_i \right) \right]} \tag{10}$$

where $(e_i - x_i)$ is the total amount of permits sold/bought by country *i*, given by the difference between emission targets and current emissions.

As far as the baseline scenario on an IET system without taxation of carbon permits is considered, we may single out net sellers and net buyers, by comparing the abatement targets (first column in Table 2) with the effective emission levels in a IET context (second column). We have four net sellers, namely Belarus, EU, FSU and Switzerland, while all other regulated countries have convenience to reduce CO2 emissions to a lower extent with respect to their abatement targets, matching the difference by buying permits on the international market (as clearly illustrated by simulated MACs in Figures A1 and A2 in the Appendix).[9]

Table 2- Emission levels (tons of CO2) and permits price with homogeneous tax and rebate rates

IET Countries	Kyoto target	IET no Tax	Rebate				No rebate	
			Full		Partial		Homogeneous Tax	
			(1)	(2)	(3)	(4)	(5)	(6)
Net sellers								
European Union	3,904.3	3,677.9	3,677.9	3,677.5	3,708.7	3,735.5	3,769.6	3,713.2
Former Soviet Union	2,053.9	1,634.7	1,637.4	1,642.5	1,671.5	1,696.5	1,727.9	1,670.2
Belarus	69.8	63.1	63.3	63.7	64.2	64.6	65.1	63.9
Switzerland	54.5	51.2	51.1	51.1	51.7	52.2	52.9	51.9
Net buyers								
United States	4,676.5	5,136.8	5,135.0	5,130.8	5,083.6	5,043.6	4,992.8	5,081.8
Canada	407.0	488.7	488.6	488.5	484.2	480.6	476.0	483.8
Australia	287.0	336.8	336.7	336.4	332.9	329.9	326.1	332.7
New Zealand	23.9	30.6	30.6	30.6	30.4	30.2	29.9	30.3
Japan	1,059.1	1,102.1	1,101.9	1,101.2	1,095.1	1,090.0	1,083.3	1,095.0
Croatia	19.9	21.1	21.1	21.2	21.0	20.9	20.7	20.9
Norway	29.1	41.7	41.6	41.6	41.4	41.2	40.9	41.4
Net equilibrium price ($ per ton CO2) (p_e)	-	*22.86*	*27.05*	*35.82*	*32.79*	*30.28*	*27.22*	*24.49*

While the range can be considered almost realistic the effective tax and rebate rates have been associated to our CGE regions randomly, without specific coherence with those rates reported in the OECD data country by country.

[9] Country specific MAC curves are represented in Figures A1 and A2 in the Appendix for small and large economies modelled in our GTAP-E version. Domestic marginal abatement costs relative to each national emissions target may be compared to the permits equilibrium price derived in a IET scenario, thus obtaining information on the relative position of each country in the carbon market with respect to a general equilibrium context.

The corresponding equilibrium price equals to 22.86 US$ per ton of $CO2$, which is quite consistent with the permits price values registered on the European Union carbon market (ETS) corresponding approximately to 19-20 US$ per ton of $CO2$ on average for 2010.[10]

Let us introduce a homogeneous taxation applied to permits revenue by net sellers, with a full and homogeneous rebate applied by net buyers (scenario 1). As expected by eq. (5), the net equilibrium price increases, and the price increase is proportional to the tax/rebate rate level (scenario 2), independently from the fiscal treatment adopted in each single country ($t_i \equiv \bar{t}$).

According to Figure 1 and to the theoretical model, in a fully homogeneous case emission abatement decisions remain fairly constant both for net sellers and buyers. Nonetheless, specific country features allow explaining the relative strength of the (indirect) price effect and of the effect directly related to taxation in terms of abatement decisions. Though the direct tax-related effect always prevails, coherently with eq. (6) and Remark 3, the net sellers feature a differentiated impact in terms of emissions increase. The relative position of MACs for these countries allows explaining this result. Comparing Belarus with Switzerland (Figure A1) and FSU with EU (Figure A2) it is worth noticing that in both cases the MACs above the IET no Tax equilibrium price are divergent, with Belarus and FSU showing higher abatement costs with respect to Switzerland and EU respectively, giving to $B''(x_i)$ a crucial role.

In terms of net economic effects on the partial equilibrium side, due to the permits price increase, the net sellers are going to gain with respect to the IET no Tax scenario since the net revenues from taxing permits (permits revenue) sum up to the permit value resulting in a net gain (Table 3). For net buyers a full defiscalization of abatement costs equalizing tax rates by net sellers (hereafter referred as a full rebate case) has a negative impact due to the increase in the equilibrium price, which implies an increase in permits value as well as an additional cost related to financial support (or defiscalization) to buy permits on the market.

For the net sellers the relation between net revenue and the average tax rate is unambiguously of the type:

$$\frac{\partial R_i}{\partial \bar{t}} > 0 \tag{11}$$

Coherently with Remark 4, the revenue always decrease with the rebate rate for the net buyers. Summing up, when homogenous tax and rebate rates are applied, the net equilibrium price raises,

[10] Countries result as net sellers or buyers depending on multiple dimensions as the current energy mix, the production structure as well as the specific abatement targets. Hence, our simulations are only representative as what could happen on the permits market for sellers and buyers, but not specifically to specific countries (namely EU or US or others) as results can change according to different model settings or simulation design.

while emission levels remain almost constant with respect to a IET no Tax scenario, bringing to a net gain for the net sellers and a net loss for the net buyers in net permits revenue terms.

Introducing partial homogeneous rebates, we can single out additional interesting results. Fixing the tax rates at 35% in line with scenario 2, we compare average rebate rates equal to 25% and 15% (scenarios 3 and 4, respectively) with the previous full rebate case.

With partial rebate, i.e. $\left(\bar{t}_{tax} - \bar{t}_{rebate}\right) > 0$, eq. (5) still holds, but we notice a smaller impact on net permits price, in line with the case described in Figure 1. In particular, the larger the distance between the average tax rate and the average rebate rate, the smaller the impact on the net equilibrium price. We can then conclude that

$$\frac{dp^*}{d\left(\bar{t}_{tax} - \bar{t}_{rebate}\right)} < 0 \tag{12}$$

Moreover, for net buyers we can also obtain a positive relation between tax/rebate difference and emission levels $\frac{dx_i}{d\left(\bar{t}_{tax} - \bar{t}_{rebate}\right)} < 0$.

Table 3- Net permits value, revenues and rebates with homogeneous tax and rebate rates

IET Countries	IET no Tax	Rebate: Full (1)	(2)	Partial (3)	(4)	No rebate: Homogeneous Tax (5)	(6)
				Permits value			
Net sellers							
European Union	5,220	6,184	8,205	6,467	5,152	3,705	4,723
Former Soviet Union	9,666	11,371	14,866	12,650	10,922	8,952	9,478
Belarus	155	178	221	186	160	130	147
Switzerland	77	92	124	92	69	43	65
Net buyers							
United States	-10,618	-12,514	-16,424	-13,475	-11,212	-8,681	-10,010
Canada	-1,883	-2,227	-2,945	-2,555	-2,248	-1,895	-1,898
Australia	-1,149	-1,356	-1,784	-1,516	-1,309	-1,074	-1,129
New Zealand	-156	-184	-243	-215	-193	-167	-160
Japan	-994	-1,168	-1,521	-1,193	-943	-667	-888
Croatia	-29	-34	-47	-37	-30	-22	-27
Norway	-289	-341	-451	-405	-367	-323	-302
				Permits Revenue/Rebate			
Net sellers							
European Union	-	928	2,872	2,264	1,803	1,297	708
Former Soviet Union	-	1,706	5,203	4,427	3,823	3,133	1,422
Belarus	-	27	77	65	56	46	22
Switzerland	-	14	43	32	24	15	10
Net buyers							
United States	-	-1,877	-5,748	-3,369	-1,682	0	0
Canada	-	-334	-1,031	-639	-337	0	0
Australia	-	-203	-625	-379	-196	0	0
New Zealand	-	-28	-85	-54	-29	0	0
Japan	-	-175	-532	-298	-141	0	0
Croatia	-	-5	-16	-9	-4	0	0
Norway	-	-51	-158	-101	-55	0	0

Exactly the opposite occurs for the net sellers since the higher the distance between the tax and rebate rates, the higher their emission levels. In both cases, the emission abatement decisions are strictly related to the relation between the equilibrium permits price and the average tax level as in eq. (12).

We then simulate the extreme case where a tax rate is imposed by net sellers while net buyers do not introduce rebate rates. We have assumed two cases in which the tax rate is equal to the upper or the lower bound. When a 35% tax rates is imposed (scenario 5), we may notice a smaller increase in the net equilibrium price than in the previous simulations. The relation between abatement choices and tax rates can be generalized. As it can be checked in Table 2, when higher tax rates are applied, net sellers react coherently with the theoretical model (Remark 1) and with Figure 1, reducing their abatement efforts (increasing their emissions). According to eq. (2), the domestic emission levels of net buyers are negatively correlated with the net equilibrium price. The absence of rebate implies that the total amount of traded permits is lower than in a full rebate case, and the total amount of traded permits is decreasing with the tax rate level.

These last simulations bring to divergent results in terms of net permit values. While relation (11) is confirmed, scenario 5 reveals that for the highest tax rate here considered, the contraction of the gap between MACs of certain sellers with respect to net buyers brings to a lower net permits value (permits value plus tax revenue) with respect to the IET no Tax case (i.e., EU and Switzerland), confirming again the crucial role played in our results by $B''(x_i)$.

The second set of simulations (Table 4) considers a no rebate case with lower bound of tax rate as a benchmark (scenario 6 from Table 1), whereas all net sellers except one impose the lowest tax rate (15%) and the remaining seller imposes the highest rate (35%) (scenarios 7-10).

Table 4- Alternative heterogeneous tax rates with no rebate

		No rebate				
		Hom. Tax	Heterogeneous Tax			
IET Countries		(6)	(7)	(8)	(9)	(10)
Net sellers						
European Union		15.0%	35.0%	15.0%	15.0%	15.0%
Former Soviet Union		15.0%	15.0%	35.0%	15.0%	15.0%
Belarus		15.0%	15.0%	15.0%	35.0%	15.0%
Switzerland		15.0%	15.0%	15.0%	15.0%	35.0%
Net buyers						
United States		0.0%	0.0%	0.0%	0.0%	0.0%
Canada		0.0%	0.0%	0.0%	0.0%	0.0%
Australia		0.0%	0.0%	0.0%	0.0%	0.0%
New Zealand		0.0%	0.0%	0.0%	0.0%	0.0%
Japan		0.0%	0.0%	0.0%	0.0%	0.0%
Croatia		0.0%	0.0%	0.0%	0.0%	0.0%
Norway		0.0%	0.0%	0.0%	0.0%	0.0%
Average tax rate	$(\bar{t}_{tax})$	*15.0%*	*19.4%*	*26.6%*	*15.1%*	*15.0%*
Average rebate rate	$(\bar{t}_{rebate})$	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*

This exercise allows us to consider the relative impact of country specific features, including heterogeneous tax rates, on the permits market for net sellers. In particular, the condition $t_i > \bar{t}$ is necessary to investigate more deeply Remarks 1 and 2, while the conditions $dt_i > 0$ and $dt_j = 0$ ($\forall j \neq i$) are necessary to extend to a CGE setting the conclusions obtained in Remarks 4 and 5 for the net sellers group.

Looking at abatement decisions (Table 5), net sellers' behaviour respects the condition $\frac{dx_i}{dt_i} > 0$, since the emission level for the country with $dt_i > 0$ (tax rate equal to 35%) is always higher than the benchmark case (scenario 6) where an homogenous 15% tax rate is applied $\forall i \in I$. In this way we can also better isolate the direct and indirect effect related to the tax and the price channel of abatement decisions. By considering eq. (2), we notice that the emissions level for country j decreases with p when $t_i > \bar{t}$ and also that the reactivity of x_j w.r.t. p is increasing when $t_i > \bar{t}$ ($\forall j \neq i$). Also eq. (3) is fully confirmed since the emission level increases with the tax rate ($\forall i \in I$). Moreover, eq. (5) is shown to hold ($\forall i \in I$) and, connecting to Remark 2, we can notice that the higher increases in the equilibrium price correspond to scenarios 7 and 8, where EU and FSU adopt a $t_i > \bar{t}$ respectively, corresponding to higher impacts in terms of $\frac{\partial x_i}{\partial t_i}$.

Coherently with Remark 3, we can also observe that the negative relation $\frac{dx_j}{dt_i} < 0$ between the emission levels of the other countries and the tax rate of the *i-th* country holds $\forall j \neq i$. Comparing scenarios 7-10 with the benchmark (i.e. homogeneous tax) case (scenario 6) we can also see how important is the relative impact of a change in the i-th country's tax rate on this relation, whose magnitude is strongly dependent on which country is applying a $t_i > \bar{t}$.

The permit revenues in Table 6 show that the condition $\frac{\partial R_i}{\partial t_i} > 0$ holds for all net sellers but Switzerland, where the condition $\left(p + \frac{dp^*}{dt_i} t_i\right)(e_i - x_i) > t_i p \frac{dx_i}{dt_i}$ is not respected (Remark 4). We can easily explain this result considering the relatively lower influence of small economies' taxing decisions on the equilibrium permits price. The prevailing mechanism is then likely to be associated to domestic emission abatement decisions, implying that the right hand side of the above inequality is larger than the left hand side. Finally, also Remark 5 is confirmed for net sellers since the revenue in country j increases with t_i, and the relative impact is strictly dependent on the relative strength of country i in influencing the equilibrium price.

Table 5- Emission levels (tons of CO2) and permits price with heterogeneous tax rates (no rebate)

IET Countries		Kyoto target	IET no Tax	No rebate Hom. Tax (6)	Heterogeneous Tax (7)	(8)	(9)	(10)
Net sellers								
European Union		3,904.3	3,677.9	3,713.2	3,789.5	3,692.1	3,712.8	3,712.8
Former Soviet Union		2,053.9	1,634.7	1,670.2	1,651.5	1,745.8	1,669.8	1,669.8
Belarus		69.8	63.1	63.9	63.5	63.4	65.9	63.9
Switzerland		54.5	51.2	51.9	51.5	51.4	51.8	53.6
Net buyers								
United States		4,676.5	5,136.8	5,081.8	5,038.2	5,040.6	5,080.5	5,080.5
Canada		407.0	488.7	483.8	480.0	480.3	483.7	483.7
Australia		287.0	336.8	332.7	329.5	329.7	332.7	332.7
New Zealand		23.9	30.6	30.3	30.1	30.2	30.3	30.3
Japan		1,059.1	1,102.1	1,095.0	1,089.5	1,089.5	1,094.9	1,094.9
Croatia		19.9	21.1	20.9	20.8	20.8	20.9	20.9
Norway		29.1	41.7	41.4	41.1	41.2	41.4	41.4
Net equilibrium price ($ per ton CO2)	(p_e)	-	*22.86*	*24.49*	*25.80*	*25.74*	*24.51*	*24.51*

Table 6- Net permits value, and revenues with heterogeneous tax rates (no rebate)

IET Countries	IET no Tax	No rebate Hom. Tax (6)	Heterogeneous Tax (7)	(8)	(9)	(10)
		Permits value				
Net sellers						
European Union	5,220	4,723	2,993	5,510	4,738	4,736
Former Soviet Union	9,666	9,478	10,472	8,002	9,500	9,496
Belarus	155	147	165	167	98	147
Switzerland	77	65	78	79	66	22
Net buyers						
United States	-10,618	-10,010	-9,414	-9,456	-9,999	-9,999
Canada	-1,883	-1,898	-1,898	-1,904	-1,898	-1,898
Australia	-1,149	-1,129	-1,105	-1,107	-1,128	-1,128
New Zealand	-156	-160	-164	-164	-161	-161
Japan	-994	-888	-790	-791	-886	-886
Croatia	-29	-27	-24	-25	-27	-27
Norway	-289	-302	-312	-312	-302	-302
		Permits Revenue/Rebate				
Net sellers						
European Union	-	708	1,048	827	711	710
Former Soviet Union	-	1,422	1,571	2,801	1,425	1,424
Belarus	-	22	25	25	34	22
Switzerland	-	10	12	12	10	8
Net buyers						
United States	-	0	0	0	0	0
Canada	-	0	0	0	0	0
Australia	-	0	0	0	0	0
New Zealand	-	0	0	0	0	0
Japan	-	0	0	0	0	0
Croatia	-	0	0	0	0	0
Norway	-	0	0	0	0	0

The third set of scenarios (Table 7) introduces some forms of heterogeneity in rebate rates while a homogenous tax rate is allowed for net sellers, allowing to understand the emissions abatement choices and price reactions related to heterogeneous rebate rates and to assess theoretical findings also for net buyers.

Table 7- Alternative heterogeneous rebate rates (homogeneous tax)

	Hom. reb.	Heterogeneous rebate						
		High av. reb.			Low av. reb.			
IET Countries	(4)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
Net sellers								
European Union	35.0%	35.0%	35.0%	35.0%	35.0%	35.0%	35.0%	35.0%
Former Soviet Union	35.0%	35.0%	35.0%	35.0%	35.0%	35.0%	35.0%	35.0%
Belarus	35.0%	35.0%	35.0%	35.0%	35.0%	35.0%	35.0%	35.0%
Switzerland	35.0%	35.0%	35.0%	35.0%	35.0%	35.0%	35.0%	35.0%
Net buyers								
United States	15.0%	35.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
Canada	15.0%	15.0%	35.0%	15.0%	15.0%	15.0%	15.0%	15.0%
Australia	15.0%	15.0%	15.0%	35.0%	15.0%	15.0%	15.0%	15.0%
New Zealand	15.0%	15.0%	15.0%	15.0%	35.0%	15.0%	15.0%	15.0%
Japan	15.0%	15.0%	15.0%	15.0%	15.0%	35.0%	15.0%	15.0%
Croatia	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	35.0%	15.0%
Norway	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	35.0%
Average tax rate $(\bar{t}_{tax})$	*35.0%*	*35.0%*	*35.0%*	*35.0%*	*35.0%*	*35.0%*	*35.0%*	*35.0%*
Average rebate rate $(\bar{t}_{rebate})$	*15.0%*	*30.7%*	*18.4%*	*17.2%*	*15.3%*	*17.1%*	*15.1%*	*15.5%*

We compare abatement decisions of net buyers and rebate rate levels with respect to a homogeneous partial rebate scenario taken as the benchmark (scenario 4). For the sake of simplicity, we classify the effects of heterogeneous partial rebates where the rebate rate applied by each country increases the average rebate rate for buyers by a large (scenarios 11-13) or small amount (scenarios 14-17). Regarding Remarks 1 and 2, all results confirm our findings related to the net sellers group (Table 8). Concerning Remark 4, we find that when country *i* is a net buyer, its revenues always decreases (i.e. the rebate increases) with the rebate rate.

Table 8- Emission levels (tons of CO2) and permits price with heterogeneous rebate rates (homogeneous tax)

	Kyoto target	IET no Tax	Hom. rebate	Heterogeneous rebate						
				High av. reb.			Low av. reb.			
IET Countries			(4)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
Net sellers										
European Union	3,904.3	3,677.9	3,735.5	3,692.1	3,731.8	3,732.6	3,735.5	3,730.2	3,735.5	3,735.5
Former Soviet Union	2,053.9	1,634.7	1,696.5	1,656.1	1,693.2	1,693.4	1,696.3	1,691.4	1,696.3	1,696.3
Belarus	69.8	63.1	64.6	63.9	64.5	64.5	64.6	64.5	64.6	64.6
Switzerland	54.5	51.2	52.2	51.4	52.2	52.2	52.2	52.1	52.2	52.2
Net buyers										
United States	4,676.5	5,136.8	5,043.6	5,163.4	5,033.4	5,035.8	5,043.0	5,030.3	5,043.0	5,043.0
Canada	407.0	488.7	480.6	470.1	499.6	479.9	480.5	479.5	480.6	480.5
Australia	287.0	336.8	329.9	321.7	329.2	345.6	329.8	328.8	329.8	329.8
New Zealand	23.9	30.6	30.2	29.7	30.1	30.1	31.2	30.1	30.2	30.2
Japan	1,059.1	1,102.1	1,090.0	1,075.2	1,088.8	1,088.8	1,089.8	1,116.1	1,090.0	1,089.8
Croatia	19.9	21.1	20.9	20.6	20.8	20.8	20.9	20.8	21.4	20.9
Norway	29.1	41.7	41.2	40.6	41.1	41.1	41.2	41.1	41.2	42.2
Net equilibrium price ($ per ton CO2) (p_e)		*22.86*	*30.28*	*34.43*	*30.61*	*30.57*	*30.30*	*30.75*	*30.29*	*30.30*

Also a revenue related spillover is confirmed for the net buyers group, and according to Remark 5 eq. (9) has a positive sign only for those countries where the condition $\left(e_j - x_j\right)\frac{dp^*}{dt_i} > p\frac{dx_j}{dt_i}$ is respected (Table 9).

Table 9- Net permits value, revenues and rebates with heterogeneous rebate rates (homogeneous tax)

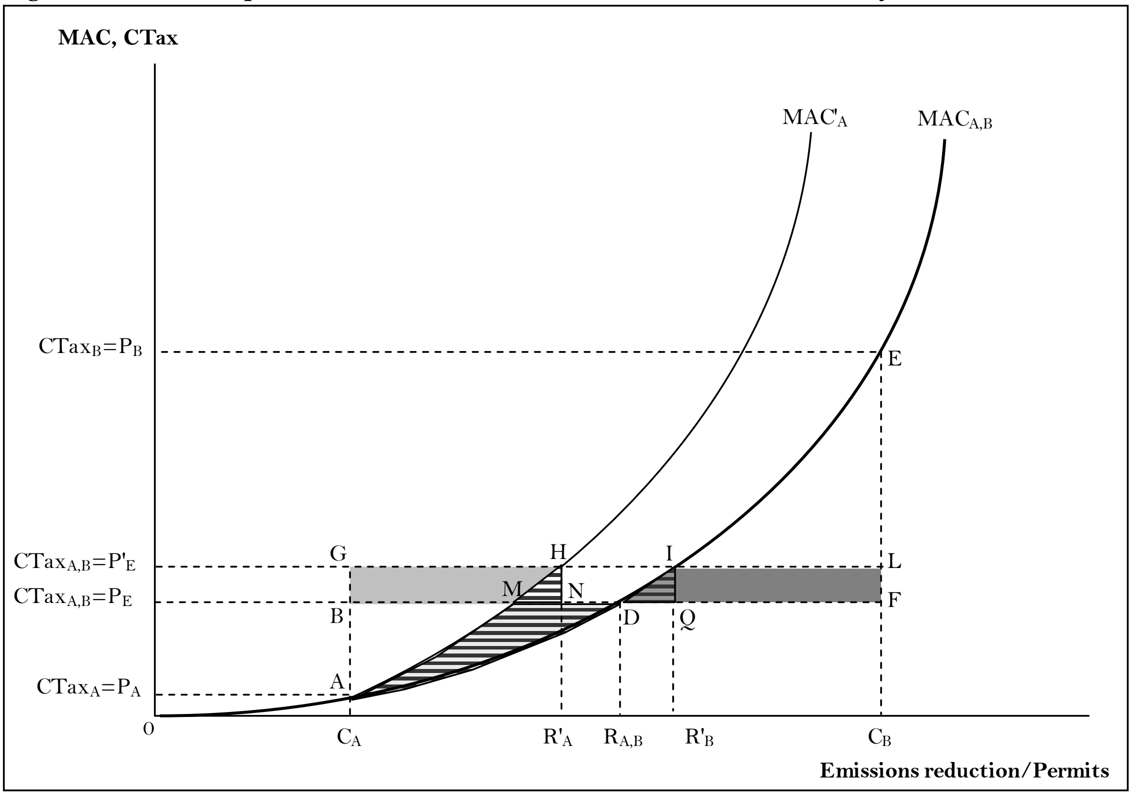
IET Countries	IET no Tax	Hom. reb. (4)	Heterogeneous rebate: High av. reb. (11)	(12)	(13)	(14)	Low av. reb. (15)	(16)	(17)
			Permits value						
Net sellers									
European Union	5,220	5,152	7,369	5,322	5,293	5,161	5,398	5,158	5,162
Former Soviet Union	9,666	10,922	13,822	11,140	11,115	10,932	11,242	10,928	10,933
Belarus	155	160	205	163	163	160	165	160	160
Switzerland	77	69	109	72	71	69	73	69	69
Net buyers									
United States	-10,618	-11,212	-16,919	-11,024	-11,076	-11,203	-10,968	-11,208	-11,204
Canada	-1,883	-2,248	-2,192	-2,859	-2,249	-2,248	-2,248	-2,248	-2,248
Australia	-1,149	-1,309	-1,207	-1,302	-1,807	-1,308	-1,296	-1,309	-1,308
New Zealand	-156	-193	-202	-194	-193	-224	-194	-193	-193
Japan	-994	-943	-561	-917	-917	-941	-1,772	-942	-941
Croatia	-29	-30	-26	-30	-30	-30	-30	-47	-30
Norway	-289	-367	-399	-370	-370	-368	-371	-367	-399
			Permits Revenue/Rebate						
Net sellers									
European Union	-	1,803	2,579	1,863	1,852	1,806	1,889	1,805	1,807
Former Soviet Union	-	3,823	4,838	3,899	3,890	3,826	3,935	3,825	3,827
Belarus	-	56	72	57	57	56	58	56	56
Switzerland	-	24	38	25	25	24	26	24	24
Net buyers									
United States	-	-1,682	-5,922	-1,654	-1,661	-1,680	-1,645	-1,681	-1,681
Canada	-	-337	-329	-1,001	-337	-337	-337	-337	-337
Australia	-	-196	-181	-195	-632	-196	-194	-196	-196
New Zealand	-	-29	-30	-29	-29	-78	-29	-29	-29
Japan	-	-141	-84	-138	-138	-141	-620	-141	-141
Croatia	-	-4	-4	-4	-4	-4	-4	-16	-4
Norway	-	-55	-60	-55	-55	-55	-56	-55	-140

5. Welfare analysis

The impact of permits taxation on welfare is expected to depend both on "pure" cost effectiveness considerations and on broader effects related to the interaction of the permits market with the whole economy.

Let us first discuss some broad considerations on cost effectiveness of carbon market taxation for net sellers and buyers derived from a relative comparison on gains and losses with respect to the case where emission trading is not allowed. In Figure 3 we represent the simplest case where permits are taxed in the selling countries while buyers do not apply any rebate. When a IET is implemented, we can derive the cost effectiveness of emissions trading by comparing abatement costs and permits revenues in the two cases, with and without IET. Starting from a homogeneous marginal abatement cost as in Figure 1, country A (the seller) will face a total abatement cost equal to $0AC_A$ or to $0DR_{A,B}$ in the case of domestic actions or participating to a carbon market, respectively. In the case of IET, the increasing total abatement cost is more than compensated by permits revenue ($C_ABDR_{A,B}$) bringing to a net gain equal to the area ABD. On the contrary, country B will face a reduction in total abatement costs equal to $R_{A,B}DEC_B$ covered only partially by payments for emission allowances on the carbon market ($R_{A,B}DFC_B$), resulting in a net gain (DEF). So we can demonstrate the (standard) cost effectiveness result related to IET with respect to the domestic actions (no IET) case.

Figure 3 - Effects of permits taxation on abatement costs for sellers and buyers



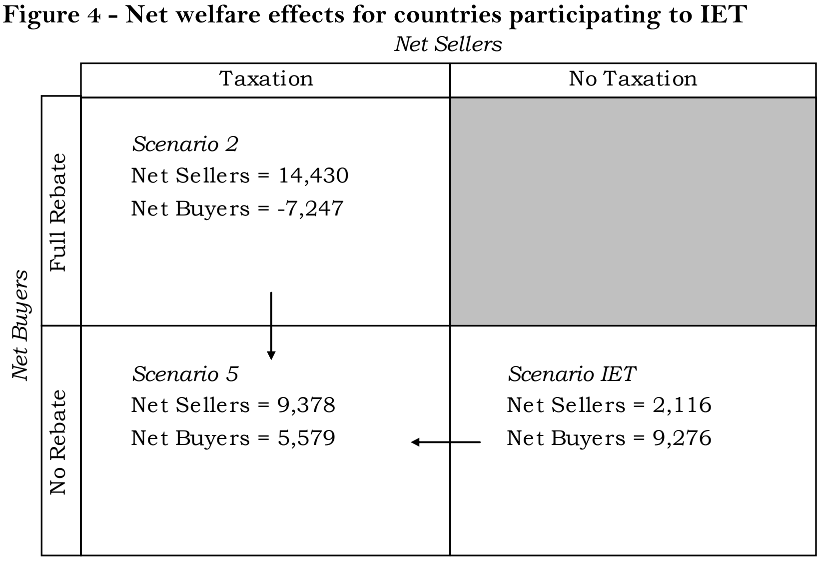
When country A imposes a tax rate on permits sold in the carbon market, the new equilibrium price will result in P'_E , where country B will find less convenience in buying permits. The new net gain with respect to a no IET case for buyer will result in IEL, with a net loss equal to DILF. For country A the final result is not obvious. The new MAC'_A corresponds to a net gain with respect to a no IET case given by the area AGH, which has to be compared with area ABD. The difference is determined by the relative size of areas BGHM and AMD. More specifically, the seller will gain from taxing carbon permits if and only if BGHM>AMD, which is coherent with Remark 4. The net effect for sellers may result in a net gain depending on to which extent the tax rate is transferred on the market equilibrium price, or in other words to the relative elasticity of supply and demand curves, which in turn depends on marginal abatement cost curves.

The net result for regulated countries as a whole is negative. The area QILF is by construction equal to BGHN, where gain for country A (BGHM) covers net loss of buyers only partially, resulting in a net loss for country B equal to MHN+DIQ. The overall loss for regulated countries will result as the sum of net loss for buyers (MHN+DIQ) and net loss for sellers (AMD). Nonetheless, this result tells us only one part of the story, since it considers only abatement costs effects (in a partial equilibrium setting as described in the theoretical model), while a general equilibrium approach provides more realistic MAC curves, also considering sector specialization as well as terms of trade effects including also non regulated countries.

To this purpose, let us now enrich the discussion turning to the global welfare effects by using the net equivalent variation in a general equilibrium framework, given by CGE simulation results. In this way we can also include the allocative efficiency effects of different abatement decisions (when allocation of resources changes relative to different tax treatment) and terms of trade effects related to the world market (related to changes in export relative to import prices), as discussed by Hanslow (2000) and Hurt and Hertel (2000). According to the analysis described in Figure 3, the equivalent variations for all scenarios have been ranked according to the relative effect with respect to a domestic policy scenario without emissions trading, for two aggregate regions representing net sellers and net buyers.

The right bottom part of Figure 4 represents our benchmark, with no tax and rebate applied to emission permits. This case corresponds to the best scenario in welfare terms for the net buyers as their welfare gains with respect to a domestic policy scenario is maximized compared to all other cases. On the contrary, the net sellers are gaining the most when a homogeneous tax rate is applied, and the higher the tax rate the higher their welfare improvement. Moreover, the lesser the distance between the tax and rebate rate, the larger the increase in net sellers' equivalent variation. As a result, the favourite scenario for net sellers corresponds to the 35% homogenous tax rate with full rebate (scenario 2), where net buyers are going to loose the most with respect to the no tax case.

Figure 4 - Net welfare effects for countries participating to IET



When a full rebate is introduced (scenario 2 in the left top side of Figure 4), the net sellers' welfare gains will be maximized while the buyers' will face the strongest loss, thus resulting in a higher net welfare loss for the abating countries as a whole with respect to the IET No tax case. This specific result may well be explained by the role of allocative efficiency effects in the net buyers group. From Figure 1, introducing a full rebate corresponds to a left-side shift of the

MAC_B, thus resulting in a net permits equilibrium price higher than in the IET-no tax case, increasing substantially the abatement costs for net buyers. This outcome is inefficient with respect to the international allocation of emission reduction efforts, resulting in a net welfare loss for countries participating to a IET system as a whole. Hence, when the overall welfare equivalent variations are scrutinized, the socially desirable design of emissions trading taxation at a global level requires a homogenous tax rates and no rebate. Thus, the resulting equilibrium solution minimizing negative welfare effects seems to be scenario 5, with the highest tax rate imposed by sellers and no rebate allowed by net buyers.

As a final remark, allocative efficiency effects for net sellers are strongly driven by domestic tax decisions. By considering scenarios 7-10, where only net sellers adopt a tax regime on emission permits, there is a direct relation between domestic tax rate and welfare in the form $\frac{dW_i}{d(t_i - \bar{t})} > 0$, where the relative magnitude of this relation is mainly explained by country-specific MAC. For instance, when EU or FSU adopt a 35% tax rate while all other sellers have a 15% rate (scenarios 7 and 8 respectively), the allocative efficiency gains are relatively higher for EU than for FSU, and this is well explained by differences in MACs of the two countries for permits equilibrium prices higher than the IET No tax case[11].

6. Concluding remarks

Emissions trading is increasingly used in practice, due to its desirable theoretical properties, the most well-known being its ability to achieve a given emission reduction target at the lowest cost. A substantial amount of literature has recently tested the robustness of such results to several extensions. We put ourselves in this stream, by taking a first step in the evaluation of environmental and welfare performance of emissions trading when permits revenues taxation and permits costs rebates are explicitly accounted for.

This paper is intended as a starting point, so that several issues are left open. However, the main message of our work is both theoretically and policy relevant. Under a theoretical point of view we add to the existing literature by explicitly assessing the impact of permits taxation on equilibrium price and emissions as well as on tax revenues. We complement theoretical results by developing a CGE simulation model, where the net buying or selling behaviour of countries as well as welfare are investigated. Under a policy point of view, we show that conjectures from previous papers can be rigorously proved: the design of permits trading taxation is not expected to be neutral in terms of environmental effectiveness and economic efficiency. Also, welfare

[11] Results for EV disaggregated factors at country level are available upon request from the authors.

analysis suggests that the welfare optimum might not coincide with the most preferred option for buyers or sellers.

Finally, although simulation results are based on specific scenarios, we deem them as realistic so that we can expect our conclusions to be general, at least in qualitative terms.

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Appendix – Model settings and MAC curves for abatement levels

Table A1- Regional and Sector aggregation

Regions	Sectors
	Primary sector
Bloc Annex I	Agriculture
Australia	*Energy products*
Belarus	Coal
Canada	Crude oil
Croatia	Electricity
European Union	Gas
Former Soviet Union	Refined oil products
Japan	*Manufacturing sector*
New Zealand	Chemical, rubber, plastic products
Norway	Electronic equipment
Switzerland	Food industry
United States	Machinery equipment
	Metal products
Bloc non-Annex I	Mineral Products
Brazil	Motor vehicles and parts
China	Other Manufactures
India	Paper products
Mexico	Textiles and Leather
South Africa	Transport equipment
Energy Exporters	*Service sector*
Rest of Africa	Air transport
Rest of America	Transport
Rest of Asia	Sea transport
Rest of Europe	Services

Figure A1 – MAC curves for small countries participating to IET calculated by GTAP-E

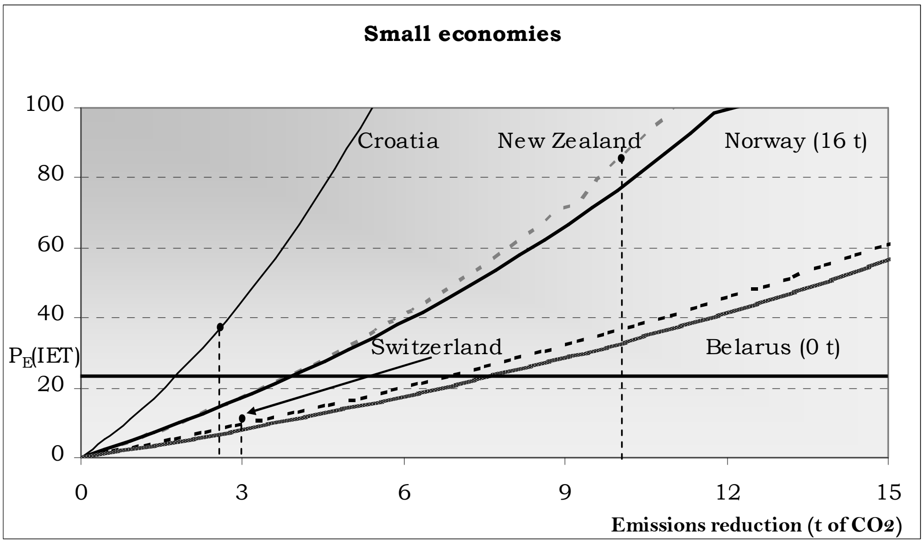

Figure A2 – MAC curves for large countries participating to IET calculated by GTAP-E