TAXING INTERNATIONAL EMISSIONS TRADING

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Taxing International Emissions Trading.

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Abstract

Most of the tradable permits regimes have ignored the role of emission allowances taxation, while recent attention by OECD and the EU has emphasized its great role. The aim of our paper is to take a first step towards the investigation of the effects of taxation on permits market. The paper is divided in two parts. The former illustrates a simple theoretical model featuring i representative competitive firms/countries. Firms take emission permits taxation as well as permits endowments as given and choose emissions and permits selling or buying behaviour. In the latter, we test our theoretical findings using a modified version of the GTAP-E model, which includes permits taxation. Our theoretical results show that explicitly accounting for emission permits taxation implies a distortion in equilibrium permits price. More specifically, taxing revenues from permits trading implies an upward shift in the equilibrium price. Moreover, the effect on the permits price due to an increase in the tax rate of a given country depends in a complex way on both industrial characteristics and the tax rate level of that country. The CGE simulations allow us to analyse our theoretical findings in a more realistic setting, giving a quantification of the response by the permits market to different tax rates as well as to different structural features at country level. Finally a preliminary tax incidence and welfare analysis suggests theoretical and empirical directions for further research.

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1 Introduction

In the context of international environmental negotiations, tradable emission permits have emerged as an economically efficient and effective means of implementing environmental policy objectives. It is well known that cap-and-trade regulations allow overall emission reduction targets to be met at lower costs than conventional command-and-control mechanisms, as they provide an opportunity to take advantage of differences in marginal abatement costs across emission sources. Under trading-based mechanisms, governments allocate a given amount of emission permits, consistently with a predefined ceiling. Firms can then trade permits among each other on the basis of their market price. Specifically, a firm holding permits can decide to emit the corresponding volume of greenhouse gases, to buy other permits and increase the amount of GHG produced, or to spend more on abating emissions and sell its surplus permits.

Despite an extended literature have examined the issue in several respects, there is a relevant aspect that has not been fully addressed to date: the tax treatment of emission permits. According to OECD, most of the tradable permit regimes have ignored the role of corporate and personal income tax and Valued Added Tax (VAT), implicitly assuming that tradable permits would be outside these tax regimes or that the impact of taxes would be neutral. In practice, however, the fiscal treatment of emission permits represents a very important aspect of cap-and-trade regulations. Taxing tradable permits may introduce distortions in their efficient allocation, by affecting the costs of acquiring permits and the proceeds from their selling. Failing to consider potential (dis)incentives effects of taxes on permits revenue could then lead to wrong conclusions about the desired level of GHG reductions and the related costs.

According to Estrada et al. [6] explicitly referring to the EU Emissions Trading Scheme (ETS), a proper tax treatment is crucial in order to avoid that certain emission permits transactions are undertaken exclusively for fiscal reasons, involving distortions such as industries relocation or non fulfilment of delivery obligations of some Member States.

How to impose a fiscal treatment concerns both the role of corporate and personal income tax and the VAT. Directive 2003/87/EC makes no reference to the accounting and fiscal repercussions of the emission permits allocation or transfer. Whilst the corporate income tax is a direct tax of exclusive competence of EU Member States, the VAT is harmonized at EU level and then the Directive is particularly surprising. The objective of harmonising domestic accounting standards for applying the corporate tax on emission permits - and then implementing a neutral tax treatment – has not been attained yet. In December 2004, the International Financial Reporting International Committee published a first draft on the best interpretation of the standards applicable to emission rights, but it was lately withdrawn due to the lack of consensus. Then firms have no guide to apply international accounting standards with the necessary homogeneity.

The disparity in fiscal regulation and in accounting standards related to different operations in the emission permits market allows for fiscal planning in corporate tax inside the EU. In particular, differences between Member States can be associated to various aspects, among which the accounting nature of emission rights, the burden of initial allocation and transfer, the deductible character of penalty resulting from non-fulfilment of the delivery obligation and the tax breaks for emission rights transfers. Concerning the burden of initial allocation and transfer, the existence of substantial differences between Member States in corporate tax rates, which range from 35% and 10%, can distort the proper functioning of emission trading market, affecting both the location of 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. Hungary, for instance, has introduced a special treatment with a discount of 50% on the tax base for the transfer of emission permits not allocated free of charge by the state. To this discount is added a corporate tax rate of 16% and other tax breaks for interests and dividend, making the opportunity of fiscal planning very attractive.

The present work is a first step in the direction of investigating the tax treatment of emission allowances, both from a theoretical and an empirical perspective. To this end, we introduce a simple model featuring i countries and i "representative" competitive firms, one in each country. Firms take emission permits taxation, as well as permits endowments, as given and choose emissions and permits selling or buying behaviour. Theoretical results show that the tax treatment of emission permits involves distortions both in terms of equilibrium permits price and in terms of 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's specificities.

Theoretical outcomes are then supplemented by a CGE model, where more realistic features of the international emissions trading system under scrutiny can be analysed. Specifically, whilst in the theoretical model we cannot consider the role of country's characteristics (technology, tax burden, and so on) in the permits allocation, empirical simulations admit such a possibility and account for countries' differential impact on equilibrium prices.

Several scenarios are aimed at using a modified GTAP-E model in order to evaluate the consequences of asymmetries in tax rates, and of the rebates inclusion or absence. Some interesting though preliminary welfare and incidence analyses are also performed.

Most of the papers considering emissions trading jointly with tax issues deal with the goods and the bads of overlapping regulatory instruments (Johnstone [10], Boehringer et al. [2], Eichner and Pethig [5], Brechet and Peralta [17]). To the best of our knowledge, the only contribution that have explicitly addressed the impact of emission trading revenues taxation is Yale [21]. This paper examines theoretically the extent to which income taxation interferes with cap-and-trade environmental regulation. Yale [21] reaches 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). It is particularly true when permits are provided freely (gratis) and their value is excluded from taxable income (holders with a zero basis in their permits). In these cases permit prices 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 emissions allowances.

Our paper takes a further step towards a full investigation of the consequences of emissions trading taxation, in line with what is suggested by the OECD. More specifically, we want to contribute to the existing knowledge by explicitly modeling permits revenue taxation in a realistic setting where multiple firms and multiple countries interact. Further, we build up a comprehensive computational general equilibrium model to investigate in a deeper way theoretical results.

The rest of the paper is organized as follows: the next section presents the theoretical model and section 3 introduces the GTAP-E model. Section 4 provides some insights on how the results obtained with simulations compare to the theoretical ones. Section 5 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 firms that can be dealt with as I representative firms, one in each country. Each firm generates polluting emissions x_i. Firm's i 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 $B_i''(x_i) < 0$. Each firm i receives an 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 benefit 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 $x_i > e_i$). The first order conditions of the firm's maximization problem is

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

which suggests that, whenever $t_i \neq t_j$ $(i, j = 1, ...I$; and $i \neq j)$, the taxation (rebate) of revenues (costs) arising from permits trading implies a violation of the cost effectivness condition (i.e. $B_i'(x_i) = B_j'(x_j)$ for any $i, j = 1, ...I$)

By totally differentiating (1) we get:

$$B_i''(x_i)dx_i - dp(1-t_i) + pdt_i = 0$$

which implies the following comparative statics results:

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

and

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

The signs of (2) and (3) define how the the level of x_i changes when, for a given level of t_i, p increases and when, respectively, for a given level of p, t_i increases. 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. Moreover, from a further 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 $B_i(x_i)$.*

Remark 1 contains interesting insights on what we should observe in a real context where different countries present different industrial characteristics and different institutional settings. As a matter of fact, the behavior of $B_i(x_i)$ (its slope, its concavity, and so on) are informative of country i industrial and technological characteristics, as well as t_i captures an important institutional aspect related to the tax burden of country i. Therefore, according to what is stated in Remark 1, we expect that these characteristics will play a role when we simulate a more realistic international ITS in the CGE model run by GTAP.

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 $dt_j = 0$ for any $j = 1, ...I$, $j \neq i$, we can rewrite the total differential as

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

and show that the equilibrium price increases with tax rates of any country i, that is

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

It is interesting to note that, from a further analysis of (5), we can 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 $\frac{\partial x_i}{\partial t_i}$ and $\frac{\partial x_i}{\partial p}$ depend on the concavity of $B_i(x_i)$, Remark 2 seems to suggest that also the reactivity of p w.r.t. t_i depends on $B_i''(x_i)$. However, the greater is the absolute value of $B_i''(x_i)$, the lower are 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. As a consequence, the overall effect of the concavity of $B_i(x_i)$ (or loosely speaking, the effect of the industrial characteristics of country i) is indeterminable in the theoretical framework used in this paper, unless some ad hoc specification is introduced on the functional form of $B_i(x_i)$. Nonetheless, instead of resorting to specific functional forms - that could be an option suffering from some degree of arbitrariness - we leave the task of analyzing how the international permits' price reacts to variations in the tax regime of different countries to the GTAP simulations where variables are calibrated to the model in the most realistic way.

Another open issue relates to the overall effect of t_i on x_i. Eq. (3) tells us that there exists a positive direct effect. Nonetheless, there is also a negative indirect effect passing through the equilibrium price of permits. Indeed, by equations (2) and (5) we also know that an increase in t_i implies an increase in p^* which, in turn, implies a reduction of x_i. As we will see in the CGE model, there exists situations where this negative indirect effect overcomes the positive direct effect and some net buyer countries can react to an increase in the tax level by reducing the demand of permits.

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 therefore to the tax revenue, defined as

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

we get the following

$$\frac{\partial R_i}{\partial t_i} = \left(p + \frac{dp^*}{dt_i} t_i\right)(e_i - x_i) - t_i p \frac{dx_i}{dt_i} \tag{6}$$

which allows us to state that

Remark 3. *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.*

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

$$\frac{\partial R_j}{\partial t_i} = t_j(e_j - x_j)\frac{dp^*}{dt_i} \tag{7}$$

Remark 4. *The revenue in country j increases (decreases) with t_i if country j is a net seller (buyer).*

Notice that the tax rate asymmetries and the initial permits endowments in each country are likely to affect the welfare gains (losses) from increases in the tax revenues (rebates). Such changes in welfare will be subject to considerations in the simulation model introduced in the next sections.

3 A CGE Empirical Simulation

3.1 Model Description

The Computable General Equilibrium GTAP-E model is an energy-environmental version of the standard GTAP model specifically designed to simulate policies in the contest of Greenhouse Gas (GHG) 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 emission trading (Burniaux and Truong, [3]; Mc Dougall and Golub, [14]).

One of the main novelty in GTAP-E with respect to traditional GTAP model is given by including the possibility of using energy inputs, allowing substitution among factors, into both production and consumption functions. The production system allows for different degrees of substitutability: in a first level between the capital-energy composite and other production factors, and in a second level between capital and energy, where the energy composite is represented by several nests between different energy commodities. Such a production system enables to simulate technological change at every point in the nest structure, as all input-saving technological changes are included in the welfare evaluation.

In the GTAP-E model, international emissions trading (IET) as one of the flexible mechanisms described in Article 17 of the Kyoto Protocol, is modelled defining bloc-level emissions and emissions quota assuming that Annex I countries can trade carbon dioxide emission permits in an international market where only compliant countries can exchange permits.

Defining exogenously Kyoto targets for each Annex I country, it has been possible to compute a carbon tax value endogenously, so that each country meets it commitments. 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. If emission trade is not allowed, the carbon tax represents the domestic maximum marginal cost of abatement necessary to comply with Kyoto targets. Carbon taxation is modelled as tax wedges distinguished according to production, private and government consumption of domestic and imported goods.

Considering the GTAP-E formulation of how carbon tax acts in reducing CO2 emissions, we may well affirm that it is a production tax, since it is imposed upstream in the production function of each good on the basis of the specific level of fossil fuels consumption, where the after tax price paid by consumers is given by:

$$p_c = p(1 + t_{carbon}) \tag{8}$$

where the consumer price (p_c) is equal to the application of a carbon tax (t_{carbon}) to the equilibrium market price (p) before the tax. Considering the specific features of GTAP-E where all variables are computed as changes with respect to the numeraire when a certain shock is given to the model, the carbon tax level which we are used to refer as a specific taxation, namely dollars per emissions unit, is transformed into an ad valorem equivalent, as expressed by eq. (8). Transforming a specific carbon tax into an ad valorem equivalent allows to understand the specific weight assumed by carbon taxation into price changes. In order to transform a specific tax into an ad valorem equivalent, resulting in a tax rate, when considering the demand price equation, carbon tax level is multiplied by the carbon content in terms of value added of each production process, obtaining exactly the ad valorem equivalent of the specific carbon tax level.

In this paper, we introduce some changes in the GTAP-E version (McDougall and Golub, [14]),enhancing the robustness of simulation results in terms of CO2 emissions and carbon taxation to alternative policy scenarios, and explicitly treating the role of permits taxation for those countries participating to IET.

First of all, we have updated the GTAP-E dataset using the latest version of the GTAP Database version 7.1 (base year 2004) as well as the latest version of the combustion-based CO2 emissions data provided by Lee [12] for all GTAP sectors and regions.

CO2 emissions are directly linked to the energy commodities considered in the GTAP-E, such as coal, crude oil, natural gas, refined oil products and gas manufacture and distribution. CO2 emissions are produced by energy consumption from firms, government, and private households, in each case distinguishing by domestic and imported use.

It is worth mentioning that some adjustments to specific sectors and regions where emissions were not consistent with data provided by the main energy agencies (EIA-DOE and IEA) have been done. Since CO2 emissions data are assigned to each region/sector on the basis of energy input volume and emission intensity factors, we analysed country/sector specific data in order to understand which factors were driving these distortions the most. We found that for some sectors and regions the emission intensity factors were indeed much higher than the average leading to a substantial overestimation of the corresponding emissions in respect with official IEA data on CO2 emissions from fossil fuels combustion. In order to reduce such bias, we have replaced the emission intensity factors for those sectors and regions which values were out of the range -1/+1 in respect with the official IPCC emission intensity factors (Herold, [7]). On the basis of these new emission intensity factors we have calculated again CO2 emissions, obtaining new values for those sectors/regions characterized by outlier emission factors[1].

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[2].

[1] We have derived emissions from domestic and imported sources as proportional to the volumes of domestic production and imports, respectively, consistently with the methodological assumptions described in Ludena [13] and Lee [12]. Finally, following Mc Dougall and Golub [14] and Ludena [13] we converted emissions data from Gg of CO2, as they were expressed in Lee [12], into Million tons of Carbon.

[2] The underestimation is quite homogeneous across regions and sectors with the exceptions of agriculture and chemicals sectors.

3.2 Model Settings and Baseline

In order to simulate different scenarios within the Kyoto Protocol implementation an aggregation of 21 sectors and 21 regions has been done (Table 1).

(table 1 about here)

Concerning regional aggregation, we consider a complete Kyoto environment, with 11 Annex I countries/regions featuring country-specific CO2 reduction commitments, assuming that all Annex I countries (including the United States) will sign the Protocol by 2012. Regional aggregation follows a simple criterion based on differences in abatement targets. Insofar, European Union 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), with a complete autonomy exerted by the European Commission in distributing specific targets internally. Even if in our aggregation the European Union has 27 Member States while the common abatement target was negotiated only for the EU 15 members, nonetheless we can easily use this common abatement objective also for the new 12 EU countries. In fact, the 12 remaining Member States when they where new EU candidate countries negotiated individually an abatement objective coherent with the single target for the EU15. It is worth noting that two small regions are also included, namely Croatia and Switzerland, since they have negotiated two distinguished emission targets[3]. 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 reallocation, and others manufacturing non-energy intensive sectors as described on the IEA Energy Balances[4].

Moreover, in our GTAP-E version some substitution elasticities in the energy nests have been replaced with those proposed by Beckman and Hertel [1], namely the substitution elasticity between the capital-energy composite and the other endowments. The substitution elasticity between capital and energy in all the nests related to the energy composite have been changed as well as the Armington elasticities according to Hertel et al. [8][5].

Finally, in order to assess an effective Kyoto Protocol environment and

[3]From the Non-Annex I bloc side, we singled out the major emerging economies, such as Brazil, China, India, Mexico, and South Africa, since they may represent the potential new bargaining power after 2012. Nonetheless, in our simulations we are not interested in investigating the effects on non compliant countries, since the IET mechanism is allowed to Annex I countries only.

[4]The Gas sector in the current aggregation includes the sector of natural gas extraction and gas manufacture and distribution.

[5]For a comprehensive discussion about substitution elasticities in the energy sector, see Koetse et al. [11], Okagawa and Ban [15], while Panagarya et al. [16] and Welsch [19] discuss the role of import demand elasticities in international trade

consequently different policy scenarios, 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.

In order to assess the performance of our modified GTAP-E model, we firstly simulated alternative carbon tax scenarios both with the standard GTAP-E and the modified version. This allowed to compare the carbon emissions changes, finding that the modified version provides results more consistent with those provided by international energy agencies such as IEA and EIA-DOE. Combined changes in emission intensity factors and substitution elasticities lead to changes in emission levels more consistent with the actual energy mix and the sectoral efficiency in reducing CO2 emissions. The improvement obtained is quite substantial, since the standard GTAP-E model provides aggregate results that in some case do not seem very realistic. As a consequence, our model version would provide a more accurate assessment of the potential extent of carbon emissions distribution after climate policies.

Specifically, the 2012 baseline scenario has been constructed in two steps. The first step has was a 2008 baseline, adjusting GTAP matrices on the basis of historical data, as provided by the Work Bank and IMF data. Therefore, in order to have emissions in line with those published in the latest IEA CO2 combustion based report (IEA, [9]) the Altertax procedure has been used to calibrate the model[6]. In fact, while the emission levels in aggregate were correct, the distribution in terms of emissions quota among regions was far from being realistic, due to the fact that exogenous technical progress in GTAP causes emissions levels to be mainly driven by output growth. The same procedure has been adopted to bring the model until 2012. The model was calibrated again for CO2 emissions with IEA projections by inducing the model to swap emissions with technical progress when emissions level at 2012, were substantially higher than those published by IEA (IEA, [9]).

We have to remind that CO2 emissions in the GTAP-E model are referred to emissions from fossil fuels combustion, as from the IEA dataset publication, while all other CO2 equivalent emissions for other activities are not included. This means that when computing CO2 reduction targets with respect to Kyoto Protocol commitments, we have accounted for such discrepancies in the computation of the 1990 emission levels, in order to have homogeneous variables related to emissions targets and 2012 baseline. Since our goal is not to provide CO2 projections but to compare economic

[6] Altertax procedure is a specific tool of GTAP aimed at change some data viewed as errors. It is an ad hoc closure which allows the model to adjust some values in the database consistently with all other data of the model, thus preserving calibration.

effects of alternative policy scenarios, we have primary considered the overall coherence of the reduction strategies with the effective distribution of abatement challenges among Annex I countries. Nonetheless our Kyoto countries emissions are almost identical to those proposed in the last IEA CO2 emission data (IEA, [9]) and in the last European Environmental Agency Report (EEA [4]).

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 an international emission trading scheme as in the Kyoto Protocol design. 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, [20]). 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. For these specific countries, 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 and their market power.

3.3 Modelling Permits Taxation

The theoretical model affirms that imposing a tax rate on carbon permits revenue affects the equilibrium price of emission trading market and also on the abatement decisions of different compliant countries. Our theoretical framework clearly shows the different options available when a taxation of emission permits revenues is introduced. In particular, net sellers countries could levy an homogeneous or heterogeneous taxation, and in this second case the impacts are completely different if the domestic tax rate is higher or smaller than the average taxation rate. Concerning net buyers, they could react to the taxation of emission permits revenues adopted by their sellers counter-parties with the introduction of full or partial rebates, in order to not charge their production costs also by the tax rates on permits purchase.

Our scenarios are aimed at using the modified GTAP-E model in order to provide an empirical validation of the different results obtained from the theoretical model. Before going into details of the alternative scenarios here proposed, a specific modification to the model equations is necessary since in the standard version emission permits are not subject to taxation. While the theoretical model assumes that each i-th country is the only agent deciding to abate more or less of its own target, and consequently selling or buying permits on the carbon market, in this CGE model abatement decisions are taken by private agents (firms and consumers). The total amount of abated emissions by private agents are then summed up at the national level and compared with emissions target. When domestic abatement is higher (lower) than the relative target, the country becomes a net seller (buyer), on the basis of a unique equilibrium price of traded permits which in turns determines also each domestic marginal abatement cost (namely the nominal carbon tax level).

In order to transfer private agents' decisions to the national abatement level, in our CGE model permits are taxed acting directly on the demand price function. The carbon equilibrium price (nominal carbon tax given by the international market) faced by agents is augmented (reduced) by an ad valorem permits tax (rebate) rate, thus influencing fossil fuels consumption behaviours of each economic agent. More precisely, the tax (rebate) rate we introduced into the GTAP-E model is uniform among economic sectors. The tax (rebate) rate can be differentiated between countries, allowing to simulate the effects related to homogeneous or heterogeneous rates.

If we consider the assumption of homogenous abatement costs among countries ($B''(x_i) = \bar{B}''$, $\forall i$), we can exemplify demand and supply effects on the permits market by addressing the effect of imposing a tax/rebate directly into abatement decisions. On the bottom side of Figure 1 the marginal abatement cost curve is assumed to be exactly the same for two countries, A and B ($MAC_{A,B}$). The only difference between the two countries is in the abatement commitment, relatively higher for B (C_B) with respect to country A (C_A). This implies that the domestic carbon tax for A ($CTax_A$ $= P_A$) necessary to be compliant with the emissions target is relatively lower than in B ($CTax_B = P_B$), allowing for the convenience to exchange emission permits.

(figure 1 about here)

Since a two countries model is here represented, 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), as a standard assumption, 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. The equilibrium point by construction gives a reduction decision which is equal for the two countries ($R_{A,B}$), resulting into $C_A R_{A,B}$ permits supplied by A (equal to $R_{A,B} C_B$ permits demanded by B). Let us now transpose such result into the top side of the graph thus obtaining an usual market representation with permits demand and supply curves, where at the equilibrium price the exchanged quantity is $0Q_E = C_A R_{A,B} = R_{A,B} C_B$.

Then, we introduce a form of tax rate imposed first by country A (the net seller), while no rebate is allowed in country B, , representing the case with no fiscal harmonization between sellers and buyers. The resulting MAC curves are no more coincident now, where country B remains on its previous $MAC_{A,B}$ while country A now is on a new leftward shifted abatement cost curve (MAC'_A)) starting from the marginal unit of emissions abated for selling it into the permits market (CA). The corresponding domestic price $MAC\prime_A$ is now higher than in the no tax case, thus reducing the propensity to sell permits into the market, or in other words reducing the abatement efforts after the target level. The new equilibrium point results into a reduced exchanged quantity on the market ($C_A R'_A = R'_B C_B$) corresponding to an higher equilibrium price. We may notice here that the net seller is going to increase its emissions with respect to the no tax case, while the net buyer now finds less convenience in buying permits, thus increasing its abatement efforts. The effects on $MACs$ produced by the introduction of a tax rate can be easily drawn in the top side of the graph, resulting into a leftward shift of the supply curve, with an higher equilibrium price (P'_E) and a lower exchanged quantity (Q'_E).

Some broad considerations on consumer and producer surplus tell us that while for country A (the net seller) the net effect may result in a net gain depending on to which extent the tax rate is transferred on the market equilibrium price, for the net buyer (country B) the imposition of a tax rate on permits results in a net loss.

Let us now assume that the buyer adopts a rebate rate, as a partial fiscal harmonization case. If a partial rebate case is considered. where the rebate rate is lower than the tax rate imposed by country A, also the abatement cost curve of country B will be affected, shifting on the left (MAC'_B) by a smaller proportion than MAC'_A. In this case the perceived abatement cost for reaching the commitment (CB) results into an higher marginal carbon tax, equal to $CTax'_B = P'_B$. The resulting new demand curve on the market side ($D\prime$) tells us that country B should find convenient to buy permits only if the market price is lower than $P\prime_B$, thus permits demand is increased with respect to the no rebate case. The abatement decisions are again associated with an equilibrium price equalizing domestic abatement costs, corresponding to an increased equilibrium price, since shifts of $MAC\prime_A$ and $MAC\prime_B$ are in the same direction with respect to $MAC_{A,B}$.

The resulting emission permits available in the market are now increased with respect to the no rebate case, since the reduction decision by A is higher than in the previous case ($R\prime_A < R''_A < R_{A,B}$), and also the abatement efforts by the net buyer are higher ($R\prime_B > R''_B > R_{A,B}$). The new equilibrium price is now higher than in the no taxcase, while the market dimension is more similar to the no tax case ($Q''E$). In the extreme case where full fiscal harmonization is considered, also the $MAC\prime_B$ will coincide with the new $MAC\prime_A$, thus resulting in a net equilibrium price increase relative to the same permits market dimension than in the no tax case.

3.4 Modelling Alternative Permits Taxation Scenarios

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

(figure 2 about here)

The first scenario simulates an International Emission Trading (IET) system without taxation of carbon permits. This is our baseline in order to assess the impact of different options for taxing emission permits revenues in net sellers countries, with and without rebate in net buyers countries, with respect to a no tax situation. The first scenario provides useful information for distinguishing countries as net sellers or net buyers: in this way, taxation on permit revenues is introduced in a more realistic setting where different countries take their abatement decision to comply with their Kyoto emission targets.

The other scenarios evaluate several features arising from the theoretical model, where specific assumptions should be tested separately.

From the first set of scenarios (Table 2) it is possible to assess the impact of the introduction of a tax rate on emission permits revenues with respect to the IET without permit taxation scenario (hereafter referred as IET-No Tax). In particular we test the overall effects on the permits equilibrium price as well as on emissions 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 rebate rates are positive (scenarios 3-4), so that the gap depends only on the net buyers decisions concerning the fiscal treatment of emission permits. 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 net sellers, with zero rebate (scenarios 5-6).

The second set of scenarios (Table 3) starts from a no rebate case with lower bound of tax rate as a benchmark (scenario 6 from Table 2), assuming a maximum tax rate for only one country (scenarios 7-10). This exercise allows to consider the relative impact of country specific structure on theoretical results, by considering the relative magnitude of the tax rate jointly with the relative specific country weight on the permits market.

The third set of scenarios (Table 4) introduces some forms of heterogeneity both in tax and rebate rates. We compare the relation between emissions abatement decisions of net sellers and the tax rate level when no rebate is applied by net buyers (scenarios 15 and 16) with respect to a homogeneous tax scenario (scenario 5). Introducing some forms of heterogeneity in the rebate rates, we finally assess the effects of heterogeneous partial rebates both in presence of homogeneous and heterogeneous taxation (respectively, scenarios 11-12 and 13-14).

(table 2, table 3 and table 4 about here)

All tax and rebate rates are taken in the range of 15%-35%, as a purely exemplificative exercise[7]. We have employed two distinguished rates related to the tax or rebate levels, in order to assess the emission decisions of net sellers and buyers separately. Abatement decisions are taken both at firm and household level on the basis of the ad valorem carbon taxation (marginal abatement cost) which is specific for each country and good according to the carbon content. In the production function abatement decisions are taken on the basis of the fossil fuels mix adopted, while in the household demand function they affect the consumption mix of polluting goods and energy services. Since the tax and rebate rates act as an ad valorem on the equilibrium price, when taxation levels are homogeneous, the average tax/rebate rate corresponds to a simple mean of the nominal tax/rebate rates applied into Annex I countries. On the contrary, when taxation levels are heterogeneous, the average tax/rebate rate corresponds to a weighted average of the nominal tax/rebate revenues on total permits value at the equilibrium market price.

4 Empirical Results from Simulation

As far as the first scenario on International Emission Trading (IET) system without taxation of carbon permits is considered, we may single out the net sellers and net buyers, by comparing the emission levels for the Kyoto targets (first column in Table 5) with the effective emission levels in a IET context (second column). It is worth noticing that we have four net sellers, namely European Union, Belarus, Former Soviet Union (FSU) and Switzerland, while all other Annex I countries have convenience to reduce CO2 emissions to lower levels with respect to their abatement targets, matching the difference buying permits on the international market. The corresponding equilibrium price equals to 22.86 US$ per ton of CO2, which is quite consistent with the current permits price on the European Union carbon market (ETS) corresponding approximately to 19-20 US$ per ton of CO2.

(table 5 about here)

Let us now introduce a homogeneous taxation applied to permits revenues by net sellers, with a full and homogeneous rebate applied by net buyers (Table 2). When an average 15% tax rate is applied with full rebate from all buyers (scenario 1), both the net equilibrium price and the after tax price increases, in line with the theoretical model (equation (5)). Moreover,

[7] 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). 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.

the price increase is proportional to the tax rate (scenario 2). Hence, with respect to Remark 2, the results from the empirical model show that, *ceteris paribus*, the introduction of some forms of taxation on permits revenues increases the after tax price levels (p_c), as

$$\frac{dp_c}{d\bar{t}} > 0 \tag{9}$$

Emissions abatement decisions remains fairly constant both for net sellers and buyers. This results is confirmed by the full fiscal harmonisation case described when commenting on Figure 1.

In terms of net revenues, due to the price increase, the net sellers are going to gain since the net permits values (at the equilibrium price) are substantially higher than in the IET-No Tax scenario. The net revenues from taxing permits (Permits revenue) sum up to the increased permit value, thus resulting in a net gain (Table 6)[8]. This case shows very clearly the added value of complementing the theoretical model with the empirical model, since the last allows to say something more with respect to Remark 3, namely it shows in which situation the net sellers face a net gain.

For net buyers a full fiscal harmonisation has a negative revenue impact due to the increase in the equilibrium price (the rebate rate acts with a negative sign): their net (negative) permits value increases. Also in this case, the theoretical model (Remark 3) is fully confirmed. Even if net effects are differentiated among net buyers, all countries face a net loss, particularly relevant for USA.

Summing up, when homogenous tax and rebate rates are applied, both the net equilibrium price and the after tax price raises. The emission levels remain the same with respect to a IET-No Tax scenario, and consequently we observe a net gain for the net sellers and a net loss for the net buyers. Moreover, such price and welfare patterns seem to be reinforced with an increasing level of tax and rebate rates. Then, comparing these scenarios with IET-No Tax, permits taxation implies an efficiency loss in the final outcome of the emission trading, represented by reducing emissions at the lowest abatement cost.

(table 6 about here)

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

With partial rebate $\left(\bar{t}_{tax} - \bar{t}_{rebate}\right) \geqslant 0$ the following holds

[8] We define Net permits value (net revenue) as Net permits value = Permit value (at the equilibrium price) + Permits revenue (from taxation or rebate). On this basis, the Net loss/gain can be computed as Net loss/gain=Revenue IET no tax – Net permits value.

$$\frac{dp^*}{d\bar{t}_{tax}} > 0 \tag{10}$$

Again, these results should be placed in the context set by Remark 2. In this case, both the equilibrium and the after tax price are still increasing (Table 5). The fact that the price increase is in both cases higher than in the full harmonisation scenarios – differently from the situation depicted in Figure 1 – may be due to different MACs between countries even before the introduction of permit taxation. The larger the distance between the average tax rate and the average rebate rate, the larger the impact on the net equilibrium price and the after tax price. We can then generalize that

$$\frac{dp_c}{d\left(\bar{t}_{tax} - \bar{t}_{rebate}\right)} > 0 \tag{11}$$

and

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

Assuming homogeneous tax and rebate rates with a partial rebate rate $\bar{t}_{rebate} > 0$ and $\left(\bar{t}_{tax} - \bar{t}_{rebate}\right) > 0$ (scenarios 3-4), for net buyers we can also generalize a positive relation between tax/rebate difference and emission levels $\frac{dx_i}{d\left(\bar{t}_{tax} - \bar{t}_{rebate}\right)} < 0$, extending the results of the theoretical model outlined in Remark 1. 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 emissions abatement decisions are strictly related to the structure of the benefits of reducing emissions, namely the industrial and technological characteristics of different countries, that at their turn are key in determining to which extent the tax burden of any tax level on permits revenues.

We will now simulate the extreme case where a tax rate is imposed by the net sellers while the net buyers have no rebate rates. We have assumed two cases where the tax rate is equal to the upper or the lower bound, and again some interesting results emerge. When a 35% tax rates is imposed (scenario 5), we may notice a small increase in the net equilibrium price compared to the other simulations. The relation between abatement choices and tax rates effects can be also generalized since the net sellers react coherently with the theoretical model (Remark 1) and with Figure 1, reducing their abatement efforts (increasing their emissions, as it can be checked in Table 5) when higher tax rates are applied. In turn, when the no rebate case is scrutinized (scenarios 5-6), 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. Moreover, the total amount of traded permits is decreasing with the tax rate level: if the tax augments then the market dimension is reduced.

The second set of simulations (Table 3) considers, a no rebate case while all net sellers except one impose the lowest tax rate (15%) and the remaining seller imposes the highest rate (35%). In this case the benchmark is an homogeneous average 15% tax rate as described in scenario 6, where the conditions $dt_i > 0$ and $dt_j = 0$ $\forall j \neq i$ are necessary to demonstrate that Remark 4 is respected.

Looking at abatement decisions (Table 7) we can notice that net sellers' behaviour respects the condition $\frac{dx_i}{dt_i} > 0$, since emissions level for the country with $dt_i > 0$ are always higher than the benchmark case (scenario 6) where an homogenous 15% tax rate is applied $\forall i \in I$.

We can also observe a second interesting result since the negative relation $\frac{dx_j}{dt_i} < 0$ between the emissions 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 case (scenario 6) Remark 4 is fully confirmed since the condition $\frac{dp^*}{dt_i} > 0$ is valid $\forall i \in I$, implying revenue gains and losses respectively for net sellers and buyers coherently with the results provided by the theoretical model. From our CGE analysis we can also see how important is the relative impact of the i-th country on this relation, whose magnitude is strongly dependent on which country is applying a $t_i > \bar{t}_{tax}$. In the case of heterogeneous tax rates, we can see that the nominal average value could not be used, and a weighted average tax rate is necessary, formally defined as

$$\bar{t}_{tax} = \frac{\sum_{i=1}^{n} \left[p(x_i - e_i) \right] t_i}{\sum_{i=1}^{n} p(x_i - e_i)} \tag{13}$$

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

From these specific scenarios we can also notice 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 3). We can explain this result considering the relative lower capacity of Swiss taxing decision to influence the equilibrium permits price. The prevailing mechanism is then likely to be associated to internal emissions abatement decision, bringing the right side part of the condition to be higher than the left side one.

Let us now turn to the third set of tax and rebate rates scenarios allowing to understand emission abatement choices and price reaction function related to heterogeneous tax rates and rebates among the net sellers and buyers (Table 4). We start from the no rebate case, introducing some heterogeneity starting from the tax rate: the four sellers, EU, Belarus, FSU and Switzerland, have heterogeneous tax rates (scenarios15-16), compared to the scenario with an homogeneous 35% tax rate (scenario 5) included in our tables as a benchmark. For the sake of simplicity we have considered two extreme cases as the two countries with the higher market power, namely EU and FSU, apply the lower and the upper bound while Belarus and Switzerland impose a tax rate taken as the average of the nominal tax rate range.

In the first case (scenario 15) the average weighted tax rate is equal to 19.5% where the EU applies $t_i > t_{tax}$ and the FSU applies $t_i < t_{tax}$, while in the second case (scenario 16) the opposite occurs and $\bar{t}_{tax} = 26.8\%$. This discrepancy can be explained by the relative higher market power played by FSU, implying that in the second case revenues from taxing permits sold by FSU are higher. If we consider how the average tax rate is computed as eq. (7), when $t_{FSU} > \bar{t}_{tax}$ the total revenues from taxing traded permits (the numerator) increases, while the permits value (the denominator) remains unchanged. This can be seen looking at Table 9: the after tax price is higher in the second case (in scenario 16 with respect to scenario 15), since $\bar{t}_{tax}$ is higher. It is also worth noticing that the after tax price assumes lower values with respect to the homogenous tax rate scenario (5), thus confirming our previous general finding (Remark 2 and eq. (10)).

(table 9 about here)

Referring to the theoretical model, we can extend Remark 1 confirming the general relation between the emissions abatement decisions and domestic tax levels with respect to an average level, since emissions levels in both scenarios 15-16 respect the condition

$$\frac{dx_i}{d\left(t_i - \bar{t}_{tax}\right)} > 0 \tag{14}$$

It is also worth noting that the net permits values for net sellers are decreasing in $\left(t_i - \bar{t}_{tax}\right)$.(Table10. More specifically, countries imposing $t_i > \bar{t}_{tax}$ are those loosing the most, see respectively EU in scenario 15 and FSU in scenario 16). The fact that EU is gaining in term of net permit value in scenario 16 may be due to a competitiveness gain in the permit market with respect to the other main seller FSU, imposing a higher tax level. This result may imply that if at least one country would gain from the heterogeneous taxation scenario with respect to the homogeneous case, then a race to bottom will be engaged among sellers in a typical free-riding problem.

(table 10 about here)

In order to introduce some forms of heterogeneous rebate, we will set an homogeneous 35% tax rate applied by net sellers, and assume a $t_{i,rebate} \in [15\%, 33\%]$ applied to net buyers randomly (Table 4, scenarios 11-12). In these cases, both the equilibrium and the after tax price are higher than in the No Tax IET scenario. We obtain results consistent with the theoretical model also when comparing different average rebate rates with the price effects, both for equilibrium and after tax price. The same line of reasoning of equation (15) may be applied to the relation between emission abatement decisions and the difference between domestic rebate rate and the average rebate rate. Comparing scenarios 11 and 12 and referring again to an extension of Remark 1, we can confirm the general relation between emissions abatement decisions and domestic rebate levels with respect to an average level, since the emissions levels in these two scenarios respect the condition

$$\frac{dx_i}{d\left(t_i - \bar{t}_{rebate}\right)} > 0 \tag{15}$$

Turning to the net permits values effects, a race to the top is the equilibrium solution as the countries with $t_i < \bar{t}_{rebate}$ are those with the smallest net loss with respect to the no rebate case (scenario 5). In general, the net permits value (negative) is decreasing with t_i, revealing that the equilibrium solution brings to a no rebate case. Moreover, remembering that the higher the difference between $\bar{t}_{tax}$ and $\bar{t}_{rebate}$, the smaller the loss in the net permits value for net buyers, the equilibrium solution for net buyers seems to be a no rebate scenario.

When a complete heterogeneity is scrutinized (scenarios 13-14), all findings ascribed to scenarios with heterogeneity only within sellers (15-16) or buyers (11-12) are fully confirmed.

5 Conclusion

In this work the tax treatment of emission permits has been investigated. We have first developed a theoretical model where n representative firms, each of them representing a different country, receive an amount of emission permits that can be traded on a perfectly competitive international market. Emission allowances are subject to taxation which affects firms' emissions and permits selling or buying behaviour. Results from the theoretical model highlight that the tax treatment of emission permits involves distortions both in terms of equilibrium permits price and distribution of environmental target across countries. Specifically, we have shown that taxing revenues from permits trading implies an upward shift in the equilibrium price, and such upward shift is stronger the larger the average tax rate. We can also argue that, given the overall emission target, the emissions distribution depends on each country's difference between own tax rate and average tax rate.

As a second step, theoretical outcomes have been complemented by a CGE model, in order to account for more realistic features of the international emissions trading system. To this end, several scenarios have been simulated by using a modified GTAP-E model allowing us to evaluate the effects of asymmetries in tax rates across countries, and the inclusion of tax rebates. Empirical simulations confirm theoretical predictions about potential welfare losses generated by permits taxation. Compared to a situation without taxation, welfare losses are always higher, even though for net sellers gains are larger when a homogeneous tax rate is applied. In this case, welfare improvement is larger the higher the tax rate. At the opposite, net buyers are going to loose with respect to the no tax case; in particular, when a full rebate is introduced, the buyers' loss is strongly increased and, given the slight decrease in the net sellers' welfare, the overall result is a net welfare loss.

Our preliminary analysis then suggests the need for policy-makers of carefully evaluating potential distortions induced by permits revenue taxation, and potential benefits arising from a tax harmonization at the EU level.

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Table 1- 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 1- Effect of Taxing permits in the case of homogeneous abatement costs

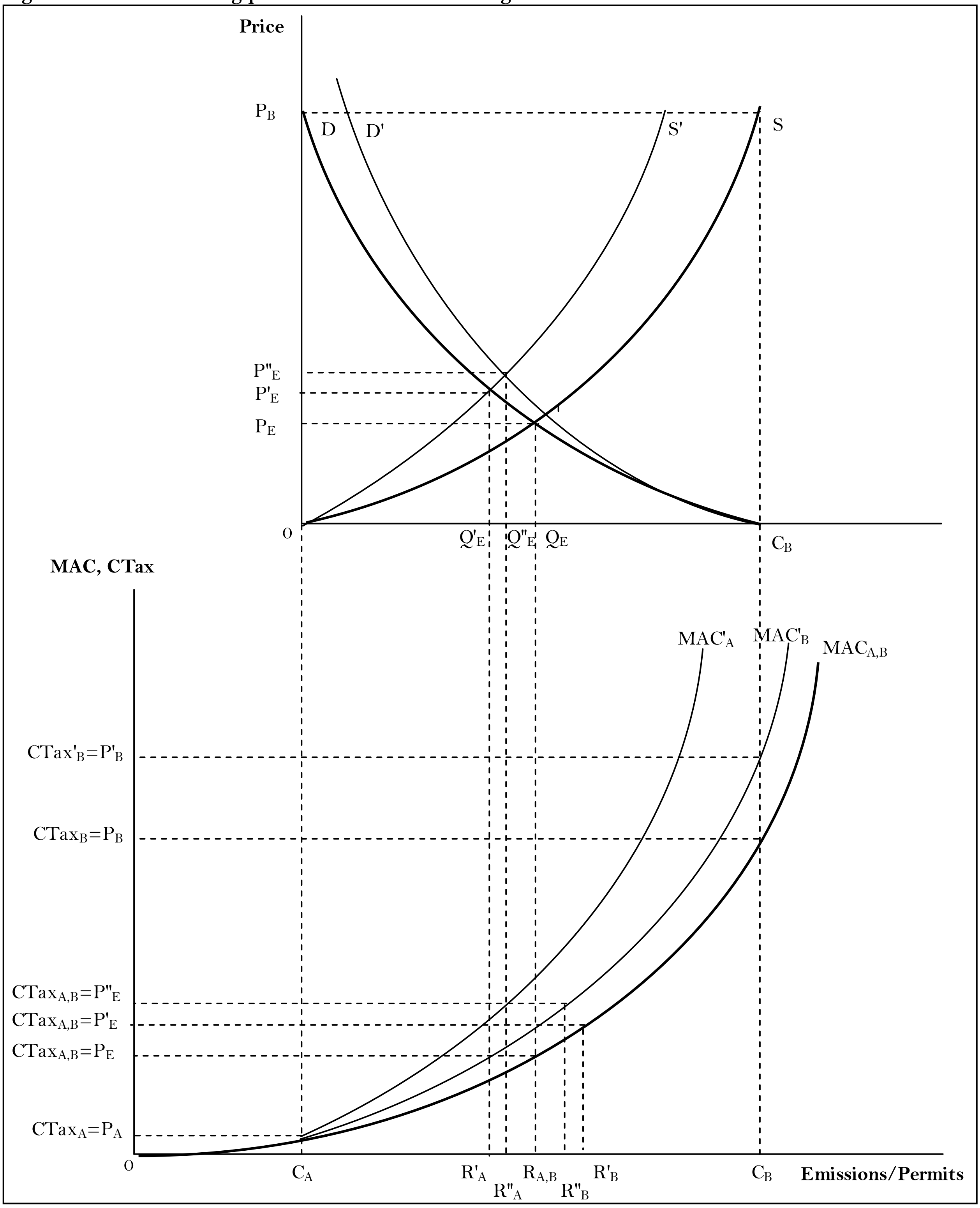

Figure 2- Diagram of alternative Tax/Rebate rates scenarios

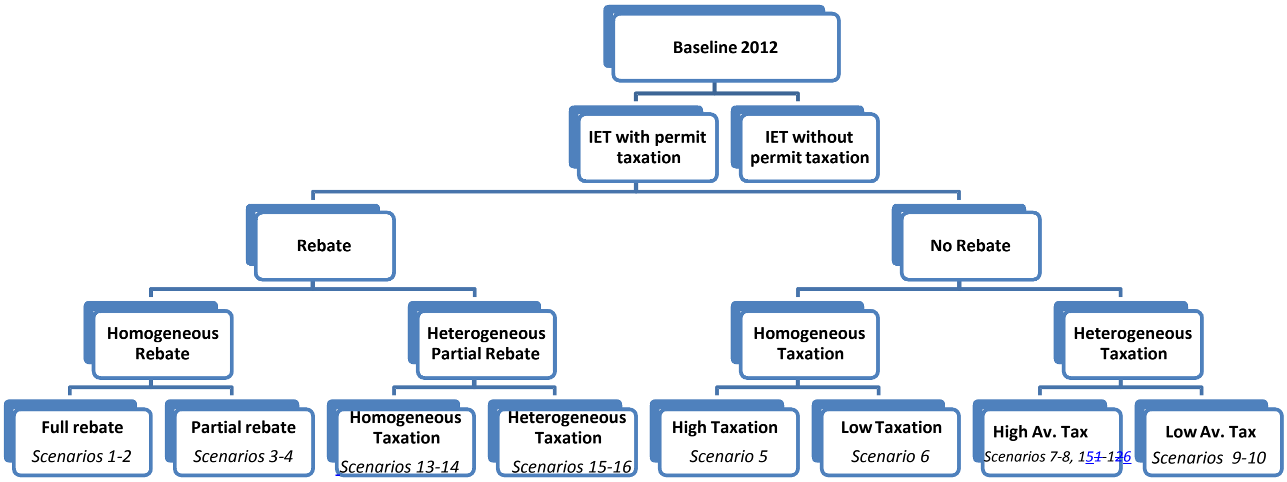

Table 2- Alternative homogeneous Tax/Rebate rates scenarios

IET Countries	Rebate				No rebate	
	Full		Partial		Homogeneous Tax	
	(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%*

Table 3- Alternative heterogeneous Tax rates scenarios with no rebate

IET Countries	No rebate				
	Hom. Tax	Heterogeneous Tax			
	(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%*

Table 4- Alternative heterogeneous Tax/Rebate rates scenarios

	Heterogeneous rebate				No rebate		
	Homogeneous Tax		Heterogeneous Tax		Hom. Tax	Het. Tax	
IET Countries	(11)	(12)	(13)	(14)	(5)	(15)	(16)
Net sellers							
European Union	35.0%	35.0%	35.0%	15.0%	35.0%	35.0%	15.0%
Former Soviet Union	35.0%	35.0%	15.0%	35.0%	35.0%	15.0%	35.0%
Belarus	35.0%	35.0%	25.0%	20.0%	35.0%	25.0%	25.0%
Switzerland	35.0%	35.0%	20.0%	25.0%	35.0%	20.0%	20.0%
Net buyers							
United States	18.0%	30.0%	30.0%	30.0%	0.0%	0.0%	0.0%
Canada	21.0%	27.0%	27.0%	27.0%	0.0%	0.0%	0.0%
Australia	27.0%	21.0%	21.0%	21.0%	0.0%	0.0%	0.0%
New Zealand	30.0%	18.0%	18.0%	18.0%	0.0%	0.0%	0.0%
Japan	24.0%	24.0%	24.0%	24.0%	0.0%	0.0%	0.0%
Croatia	15.0%	33.0%	33.0%	33.0%	0.0%	0.0%	0.0%
Norway	33.0%	15.0%	15.0%	15.0%	0.0%	0.0%	0.0%
Average tax rate $(\bar{t}_{tax})$	*35.0%*	*35.0%*	*20.6%*	*26.1%*	*35.0%*	*19.5%*	*26.8%*
Average rebate rate $(\bar{t}_{rebate})$	*20.1%*	*28.3%*	*28.3%*	*28.3%*	*0.0%*	*0.0%*	*0.0%*

Table 5- Emission levels (ton of CO2) and permits price with homogeneous Tax/Rebate rates scenarios

	Kyoto target	IET no Tax	Rebate				No rebate	
			Full		Partial		Homogeneous Tax	
IET Countries			(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*
After tax price ($ per ton CO2) (p_c)	-	*22.86*	*31.11*	*48.35*	*44.26*	*40.88*	*36.75*	*28.16*

Table 6- Net permits value, revenues and rebates with homogeneous Tax/Rebate rates scenarios

	IET	Rebate				No rebate	
		Full		Partial		Homogeneous Tax	
IET Countries	no Tax	(1)	(2)	(3)	(4)	(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
Net Permits Value							
Net sellers							
European Union	5,220	7,112	11,076	8,731	6,955	5,001	5,431
Former Soviet Union	9,666	13,077	20,069	17,077	14,744	12,085	10,900
Belarus	155	204	298	252	216	176	169
Switzerland	77	105	168	125	93	58	75
Net buyers							
United States	-10,618	-14,391	-22,173	-16,844	-12,894	-8,681	-10,010
Canada	-1,883	-2,562	-3,976	-3,194	-2,586	-1,895	-1,898
Australia	-1,149	-1,559	-2,409	-1,895	-1,505	-1,074	-1,129
New Zealand	-156	-211	-328	-269	-222	-167	-160
Japan	-994	-1,343	-2,054	-1,491	-1,084	-667	-888
Croatia	-29	-40	-63	-46	-34	-22	-27
Norway	-289	-392	-609	-506	-423	-323	-302

Table 7- Emission levels (ton of CO2) and permits price with heterogeneous Tax rates scenarios (no rebate)

IET Countries		Kyoto target	IET no Tax	No rebate				
				Hom. Tax	Heterogeneous Tax			
				(6)	(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*
After tax price ($ per ton CO2)	(p_c)	-	*22.86*	*28.16*	*30.79*	*32.60*	*28.22*	*28.20*

Table 8- Net permits value, and revenues with heterogeneous Tax rates scenarios (no rebate)

IET Countries	IET no Tax	No rebate				
		Hom. Tax	Heterogeneous Tax			
		(6)	(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
			Net Permits Value			
Net sellers						
European Union	5,220	5,431	4,040	6,337	5,449	5,446
Former Soviet Union	9,666	10,900	12,042	10,803	10,925	10,920
Belarus	155	169	190	192	132	169
Switzerland	77	75	90	91	75	30
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

Table 9- Emission levels (ton of CO2) and permits price with heterogeneous Tax/Rebate rates scenarios

		Kyoto target	IET no Tax	Heterogeneous rebate				No rebate		
				Homogeneous Tax		Heterogeneous Tax		Hom. Tax	Het. Tax	
IET Countries				(11)	(12)	(13)	(14)	(5)	(15)	(16)
Net sellers										
European Union		3,904.3	3,677.9	3,724.1	3,698.1	3,722.9	3,612.1	3,769.6	3,789.0	3,692.1
Former Soviet Union		2,053.9	1,634.7	1,685.8	1,661.6	1,577.6	1,684.0	1,727.9	1,651.1	1,745.6
Belarus		69.8	63.1	64.4	64.0	63.3	62.7	65.1	64.5	64.4
Switzerland		54.5	51.2	52.0	51.5	50.4	50.9	52.9	51.9	51.9
Net buyers										
United States		4,676.5	5,136.8	5,045.5	5,116.2	5,162.2	5,165.8	4,992.8	5,037.6	5,040.0
Canada		407.0	488.7	483.7	483.9	488.0	488.4	476.0	479.9	480.2
Australia		287.0	336.8	337.3	327.7	331.3	331.6	326.1	329.4	329.6
New Zealand		23.9	30.6	30.8	29.9	30.1	30.1	29.9	30.1	30.2
Japan		1,059.1	1,102.1	1,098.5	1,090.3	1,096.8	1,097.0	1,083.3	1,089.4	1,089.5
Croatia		19.9	21.1	20.8	21.2	21.3	21.3	20.7	20.8	20.8
Norway		29.1	41.7	42.0	40.7	41.0	41.0	40.9	41.1	41.2
Net equilibrium price ($ per ton CO2)	(p_e)		*22.86*	*31.33*	*33.82*	*31.87*	*31.76*	*27.22*	*25.82*	*25.76*
After tax price ($ per ton CO2)	(p_c)		*22.86*	*42.30*	*45.66*	*38.42*	*40.05*	*36.75*	*30.86*	*32.66*

Table 10- Net permits value, revenues and rebates with heterogeneous Tax/Rebate rates scenarios

IET Countries	IET no Tax	Heterogeneous rebate				No rebate		
		Homogeneous Tax		Heterogeneous Tax		Hom. Tax	Het. Tax	
		(11)	(12)	(13)	(14)	(5)	(15)	(16)
				Permits value				
Net sellers								
European Union	5,220	5,692	7,040	5,837	9,365	3,705	3,002	5,522
Former Soviet Union	9,666	11,635	13,389	15,316	11,856	8,952	10,488	8,016
Belarus	155	171	198	208	229	130	139	141
Switzerland	77	78	103	133	117	43	67	68
Net buyers								
United States	-10,618	-11,663	-15,008	-15,626	-15,684	-8,681	-9,404	-9,446
Canada	-1,883	-2,425	-2,624	-2,603	-2,611	-1,895	-1,898	-1,904
Australia	-1,149	-1,587	-1,386	-1,424	-1,428	-1,074	-1,105	-1,107
New Zealand	-156	-219	-206	-201	-201	-167	-164	-164
Japan	-994	-1,246	-1,066	-1,212	-1,215	-667	-789	-790
Croatia	-29	-29	-45	-47	-47	-22	-24	-25
Norway	-289	-406	-394	-380	-380	-323	-312	-312
				Permits Revenue/ Rebate				
Net sellers								
European Union	-	1,992	2,464	2,043	1,405	1,297	1,051	828
Former Soviet Union	-	4,072	4,686	2,297	4,150	3,133	1,573	2,806
Belarus	-	60	69	52	46	46	35	35
Switzerland	-	27	36	27	29	15	13	14
Net buyers								
United States	-	-2,099	-4,502	-4,688	-4,705	0	0	0
Canada	-	-509	-709	-703	-705	0	0	0
Australia	-	-429	-291	-299	-300	0	0	0
New Zealand	-	-66	-37	-36	-36	0	0	0
Japan	-	-299	-256	-291	-292	0	0	0
Croatia	-	-4	-15	-15	-16	0	0	0
Norway	-	-134	-59	-57	-57	0	0	0
				Net Permits Value				
Net sellers								
European Union	5,220	7,684	9,503	7,879	10,770	5,001	4,053	6,351
Former Soviet Union	9,666	15,708	18,075	17,614	16,006	12,085	12,061	10,822
Belarus	155	231	267	260	275	176	174	177
Switzerland	77	106	139	159	146	58	80	82
Net buyers								
United States	-10,618	-13,763	-19,510	-20,314	-20,390	-8,681	-9,404	-9,446
Canada	-1,883	-2,935	-3,333	-3,306	-3,315	-1,895	-1,898	-1,904
Australia	-1,149	-2,016	-1,677	-1,724	-1,728	-1,074	-1,105	-1,107
New Zealand	-156	-285	-243	-237	-238	-167	-164	-164
Japan	-994	-1,545	-1,322	-1,503	-1,507	-667	-789	-790
Croatia	-29	-33	-60	-62	-62	-22	-24	-25
Norway	-289	-540	-454	-437	-437	-323	-312	-312