Chapter 2
Carbon Leakage and Trade Adjustment Policies

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Abstract A modified version of the CGE GTAP-E model is used to assess economic and carbon emission effects related to alternative policy measures implemented to reduce carbon leakage. We explore a set of scenarios and compare solutions where Kyoto Annex I countries introduce carbon border taxes based on domestic carbon tax in order to solve the carbon leakage problem unilaterally and solutions where carbon border taxes are determined according to specific objectives. Results provide evidence of the scarce effectiveness of trade measures in reducing carbon leakage and enhancing economic competitiveness and the strong negative welfare effects they have not only on non-Annex countries but also on some Annex I countries.

Keywords Climate change policy • Carbon leakage • Computable General Equilibrium Model • Carbon border tax • Competitiveness

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2.1 Introduction

In recent years, a large body of the international literature as well as policy debate have expressed increasing interest in measures taken to mitigate the negative externalities of climate change policies such as the carbon leakage effect (OECD 2006). The imposition of stringent climate policies may produce substantially distortive effects in terms of displacement of production processes from countries with abating policies (e.g. carbon tax or emission trading) to countries where no climate policies are in force.

Consequently, some forms of border adjustments have been invoked in order to restore a level playing field between domestic producers and foreign exporters (Moore 2010; Wooders and Cosbey 2010).

We will elaborate on the existing studies providing further evidence of the extent of carbon leakage and the impact of different forms of carbon border tax (CBT). The major focus of this chapter is on the ambiguities surrounding the possible goals to be achieved through CBT.

In order to assess the potential economic and carbon emission effects related to CBT adjustment schemes, we use a modified version of the computable general equilibrium GTAP-E model (Burniaux and Truong 2002; McDougall and Golub 2007) described in Chap. 1. We model the pursuit of the Kyoto objectives, depicting a world where two groups exist, abating and non-abating countries. Our regional aggregation includes the 11 Annex I countries/regions with CO_2 emission reduction commitments in the Kyoto Protocol and the largest emerging economies within the non-Annex list, including Brazil, China, India and Mexico. In terms of sectoral aggregation, we distinguish 21 sectors in order to simulate the impact of alternative policies in energy-intensive and non-intensive sectors.

In order to build a benchmark for investigating the effectiveness of alternative forms of CBT, we first assess carbon leakage implied by an international emission reduction agreement such as the Kyoto Protocol by modelling two scenarios with and without emission trading. We then compare a cooperative scenario featuring global emission trading with several approaches that introduce different carbon tariff schemes to deal with the carbon leakage effect (hereafter referred to as non-cooperative scenarios).

In the cooperative scenario, Annex I countries face the emission targets defined in the Kyoto agreement whereas non-Annex countries are constrained to a zero increase in domestic emissions. By contrast, in the non-cooperative scenarios, exogenous carbon tariffs are based on the domestic carbon tax or are endogenously computed as *ad valorem* equivalents required to achieve predetermined objectives. In the former case, carbon tariffs are computed by multiplying the carbon tax either by the actual carbon content of imports or by the carbon content of the corresponding domestic good. In the latter case, the *ad valorem* tariff equivalent is either set with the aim of eliminating (or at least reducing) the carbon leakage or with the aim of maintaining the competitiveness of Annex I countries.

The economic and environmental effects resulting from alternative trade adjustment policies are compared with the results from the cooperative zero-leakage scenario. A comparison of this type highlights the advantage for non-Annex countries of changing their conservative position in the climate negotiations.

2.2 Carbon Leakage as a Side Effect of Climate Policies

2.2.1 A Definition of Carbon Leakage

Cancùn negotiations in 2010 and Durban COP17 in 2011 represented a step forward for reaching a cooperative solution, but global international cooperation for fighting climate change still seems to be a difficult goal to achieve. Policy actions to reduce greenhouse gas (GHG) emissions remain unilateral and could be undermined by the presence of carbon leakage (Hamasaki 2007). Moreover, these policies are likely to have negative impacts on the international competitiveness of some industrial sectors (OECD 2003, 2005; Veenendaal and Manders 2008).

The vast and growing literature on this issue distinguishes two typologies of leakage. The first one is caused by a shift in the location of production towards non-compliant regions, and the second one is related to an increase in energy consumption in non-abating regions due to lower prices on the international markets resulting from the reduced demand for fossil fuels in abating countries.

The pollution haven hypothesis (Copeland and Taylor 2004) explains the first type of leakage. When countries have different environmental regulatory stringency, production will be located where environmental costs are lower.

The second type of leakage can be explained by referring to the energy market model: the reduction in fossil fuel demand in abating countries leads to lower prices on the world energy markets which in turn fosters energy demand in non-abating countries (Burniaux and Oliveira 2000; Felder and Rutherford 1993).

As a matter of fact, the intensity of the taxing countries' energy demand combined with the elasticity of the energy supply curve are key drivers in determining different types of leakage. According to Gerlagh and Kuik (2007), the energy market model seems to be the prevalent explanation of carbon leakage estimates from simulation analyses.

The rate of carbon leakage is usually computed as the ratio between the increase of CO_2 emissions in non-abating countries and the reduction of CO_2 emissions in countries implementing GHG abatement policies. As reported by the Energy Modeling Forum (2000) and Kuik and Verbruggen (2002), carbon leakage rates vary widely (between 5 and 35 %, approximately) according to the model used.

Even if the implications for international trade of emission abatement policies are crucial, especially when considering their acceptability and feasibility, few studies have adopted a global approach and tried to quantify simultaneously the effects on emissions, sectoral exports, output and distributional welfare effects at country and global level (Haaparanta et al. 2001; McKibbin et al. 1999).

Carbon leakage estimates seem to be very sensitive to different model settings. Two key parameters emerge as the driving factors of highly heterogeneous leakage rates: the Armington elasticities in the import demand module and the substitution elasticities in the energy nests of the production module (Gerlagh and Kuik 2007). If Armington elasticities are low, there will be fewer opportunities for non-Annex countries to expand their exports towards compliant countries, and carbon leakage will be low. As a consequence of price impacts of emission reduction targets, non-abating countries will import less carbon-intensive commodities from Annex I countries. At the same time, given a certain value of Armington elasticities, non-abating countries will easily substitute imported intermediates from Annex I countries with intermediates from other non-abating countries or intermediates produced domestically (Wang et al. 2009), creating a demand-driven leakage effect. In this respect, higher substitution elasticities in the production function between energy and other inputs, as well as between alternative fossil fuels, would lead to larger drops in world energy price and hence to larger leakage rates (Kuik 2001).

2.2.2 How to Design Carbon Border Tax Adjustments

Abating countries may decide to impose two forms of CBT: full or partial adjustment. Full adjustment refers to a carbon tariff applied to imported goods from non-compliant countries plus a tax rebate for domestic goods that are exported. Partial adjustment refers to the application of a carbon border tax without rebates on exports (Fischer and Fox 2009).[1]

There is a growing concern over CBT as a feasible and effective unilateral policy measure for preventing carbon leakage. In particular, three major issues arise from the international literature. The first is how to design a CBT which is consistent with WTO rules, feasible in its implementation and effective in achieving its goal(s). While the carbon price in the abating country is the obvious choice as far as the value of the specific tariff is concerned, there are different opinions about how to quantify the embedded carbon in traded goods from non-compliant countries. Two alternative computation methods are often proposed. The first method applies to imported goods coming from non-abating economies where the carbon content for each good produced is given by the best available technology (BAT) in the abating country Dong and Whalley (2009), whereas the second one considers the effective carbon content of the imported goods, thus relying on the production technique applied by the producing country.

Moreover, if a direct accounting approach is considered, only carbon emissions related to the production process are accounted for. If an indirect accounting approach is implemented, all CO_2 emissions related to the production process of all intermediates are considered for the application of the CBT, leading to substantially

[1] In the rest of this chapter, the terms *carbon tariff* or *carbon border tax* will be used interchangeably.

higher implementation difficulties. Choosing the indirect emission accounting approach strongly affects carbon leakage estimates, as is shown in Atkinson et al. (2010) where the carbon tariff equivalent to a carbon price of 50$ per ton of CO_2 amounts to 10 % of the value of the average export bundle of non-abating countries, and tariffs may be two to three times higher for specific sectors.

The second issue concerns the effectiveness of CBT in preventing carbon leakage (Schenker and Bucher 2010). Empirical analyses provide contrasting results on the capacity of CBTs to reduce emissions from non-abating countries, depending both on model settings and alternative CBT designs (Dong and Whalley 2008; Mattoo et al. 2009).

A third issue relates to welfare implications of a CBT approach. The degree of political acceptance of a policy is very likely to depend on its welfare distribution effects for the different economic agents or countries affected by its implementation. CBTs clearly represent a second best solution compared with the implementation of global climate policies which would establish a uniform carbon price for all countries (Stern 2006).

2.3 Scenario Setting

The rate of carbon leakage is defined as the increase in CO_2 emissions in the rest of the world induced by the domestic reduction measures as a percentage share of the absolute value of the volume of CO_2 reduction obtained by compliant countries, according to the following equation:

$$\mathrm{CLR} = \frac{\Delta \mathrm{CO_2}^{\mathrm{Non-Annex}}}{\Delta \mathrm{CO_2}^{\mathrm{Annex}}} \times 100. \tag{2.1}$$

We first check the existence of carbon leakage in a pure Kyoto Protocol scenario, where we impose reduction targets on all Annex I countries with respect to their 1990 emission levels, as if the United States had also ratified the protocol. In particular, we assess the existence of carbon leakage both allowing for the possibility of emission trading among Annex I countries (ET scenario) and only implementing domestic measures (NO-ET scenario).[2] An adjustment of emission targets was needed since the high amount of emission permits potentially supplied by transition economies in Annex I (the FSU and Belarus in our model) would result in a close-to-zero carbon price.[3]

[2] The emission trading is modelled assuming that all abating policies can be expressed in monetary values by computing a domestic carbon tax that is applied to fossil fuel consumption. The carbon tax equals the equilibrium permits price when emission trading is introduced. This approach, which is common practice in general equilibrium modelling, enables the relative incidence of the compliance costs among countries to be assessed.

[3] This problematic issue refers to the so-called *hot air* debate and also addresses the role of the other flexible mechanisms required by the protocol (World Bank 2010). Consequently, for FSU and Belarus, the 0 % target scheduled in the protocol is applied to the emission levels in 2012 rather than the 1990 period.

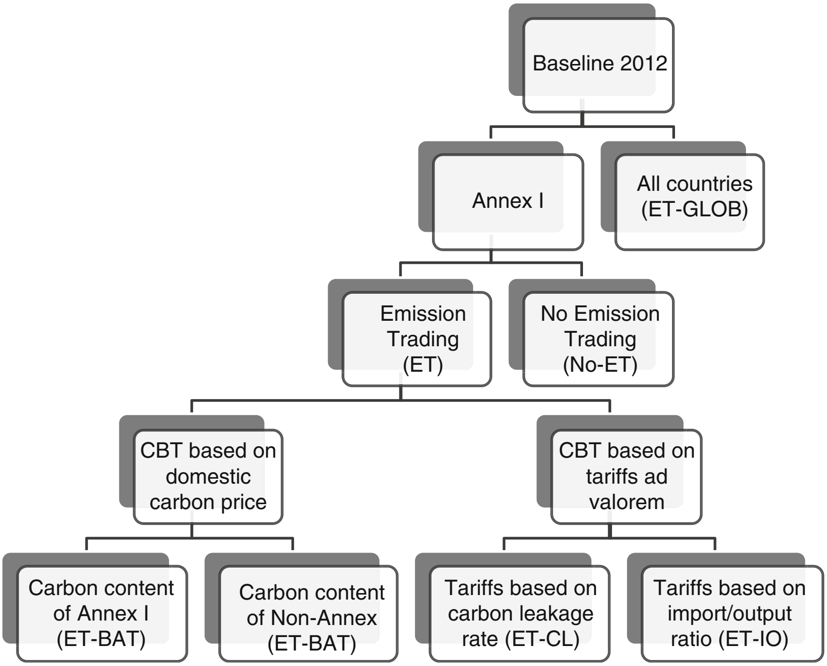


Fig. 2.1 Simulation design

The results show that emission trading is a more efficient policy instrument in terms of compliance and welfare costs both for abating countries and at global level. For this reason, we use the corresponding scenario (ET) as a benchmark for the assessment of simulations with trade adjustment policies (Fig. 2.1).

Our scenarios are based on 'one-way' CBTs applied by abating countries to all imported goods from non-abating countries.[4] Since, in GTAP-E, the carbon tax is levied on all energy products consumed in a country, both produced domestically and abroad, the carbon tariff is not applied to imported energy products.

CBTs extend the carbon tax to imports and are established in specific terms, i.e. price per ton of emissions associated with the production of each good. CBT scenarios (ET-NBAT and ET-BAT) are based on a single price for carbon emission resulting from the emission trading, but border taxes are going to differ by sector according to the carbon contents (Bordoff 2009). In the ET-NBAT scenario, border taxes are based on the carbon content of imported goods whereas in the ET-BAT scenario, they are based on the carbon content of the corresponding domestic

[4] Border tax adjustments are *two-way* when they also apply to products exported to non-Annex countries and equal the difference in indirect taxes (e.g. the value added tax) between trading partners. However, this would provide incentives to keep 'dirty' plants operating for export purposes and would make meeting the abatement commitments even more difficult for the other firms (Fischer and Fox 2009).

production in the importing country according to a BAT approach. In the latter case, all non-Annex countries face the same border tax on their exports to each Annex I country, whereas in the former case, all Annex I countries adopt the same policy implying different taxes for the same good according to the country of origin.

The ET-NBAT scenario is likely to be deemed inconsistent with WTO provisions since it discriminates between non-Annex countries as well as between domestic and imported products that are going to face different carbon taxes. The ET-BAT scenario avoids these discriminations, and it is certainly much more realistic in terms of information requirements. Nevertheless, it should be noted that the *ad valorem* equivalent of the carbon tariff depends on the import price, and this provides an obvious incentive for quality upgrading (Hummels and Skiba 2004).[5]

By comparing the performance of these two approaches for CBT implementation in terms of efficiency and effectiveness in reducing carbon leakage, we join a large and quickly growing literature. The most innovative part of this chapter elaborates additional scenarios where carbon tariffs are endogenous. The starting point of these scenarios is a given goal, either in terms of carbon leakage rate or competitiveness. The model is then used to compute the sector-specific *ad valorem* tariffs that would allow the goal to be reached.[6]

The first counterfactual scenario (ET-CL) is aimed at eliminating carbon leakage. Results show that this goal is unfeasible: even by introducing prohibitive tariffs, only a tiny share of overall non-Annex I emissions is affected, namely, the one resulting from export production. In the model, as well as in reality, emissions result from the choices of different agents whereas exports only concern firms. No tariff can intervene on the drop in energy prices caused by a decrease in the energy demand of Annex I countries, avoiding the corresponding increase in non-Annex demand.

The second counterfactual scenario (ET-IO) is focused on preserving competitiveness. Annex I countries introduce *ad valorem* tariffs so that the share of imports from non-Annex in total production in each sector of Annex I remains constant. This scenario setting reflects one of the possible interpretations of competitiveness, and other indicators may be adopted.

All the above simulations have been conceived in a non-cooperative setting where Annex I countries adopt unilateral policies in order to cope with the fact that other countries do not act to keep their emissions under control. The final scenario (ET-GLOB)[7] simulates a cooperative solution where non-Annex countries agree not to allow their emissions to increase above the 2012 baseline. This would solve the leakage problem by definition, and the introduction of emission trading at world level would represent the most efficient way of reaching emission reduction objectives.

[5] CBTs are established in specific terms (i.e. price per ton of emissions associated with the production of each good), and their *ad valorem* equivalents will be higher for goods with lower prices.

[6] In all simulated scenarios, the tariff surcharges are levied on top of the existing tariff structure by Annex I countries on all imports from the non-Annex countries.

[7] This scenario can be defined as our first best scenario in contrast with the others which can be referred to as 'second best' scenarios.

2.4 Empirical Results

We first compare the implementation of the abatement targets with and without an emission trading scheme (ET and NO-ET scenarios). Simulation results reveal that, when emission trading is allowed, there is a substantial reallocation in emission reductions. The three sellers are the EU, FSU and Belarus. All the other countries buy emission permits. The EU behaviour is hardly surprising if we consider that the new 12 member states are characterized by substantially lower marginal abatement costs and less stringent abatement constraints. The combination of these two elements explains why it is more convenient for the EU as a whole to reduce emissions below the target and sell emission permits in the international market. In line with the expected higher allocative efficiency of market-based instruments, larger abatement efforts are associated with countries with lower marginal abatement costs. As a consequence, the average domestic carbon tax level in the NO-ET scenario (\$39.16 per tCO_2) turns out to be much higher than the equilibrium price for emission permits in the ET scenario (\$22.92 per tCO_2).

Both simulations generate carbon leakage, although in the ET scenario, the leakage rate is higher than in the no trade scenario. This result can be explained by considering that the same overall emission reduction objective for Annex I countries is reached with a different abatement allocation in the two scenarios. In the ET scenario, some large economies with demanding abatement targets should implement less structural adjustments and undergo a smaller contraction, thus showing higher imports from non-compliant countries than in the NO-ET scenario. At country level, the non-Annex countries most responsible for carbon leakage in absolute terms are represented by South Africa, Rest of Europe and energy-exporting countries and – to a lesser extent – Brazil, India and China.

In terms of welfare effects, there are large discrepancies between the NO-ET and ET scenarios. For net buyers of carbon permits, in the ET scenario, there is a substantial reduction in the allocative efficiency loss since energy-intensive sectors do not have to reduce their production. In other words, the high costs associated with heavy structural adjustments in the production specialization pattern can be avoided. The countervailing effect for net buyers is the expenditure for acquiring permits on the international emission trading market. On the contrary, the emission trading revenue compensates, at least partially, net sellers for the larger adjustments they undergo.

From here on, we consider the emission trading scheme scenario as a reference scenario since its compliance and welfare costs are smaller than those associated with the domestic carbon tax scenario, even if it is not likely to materialize in the near future. Moreover, since the leakage effect is larger, the endogenous carbon tariffs will constitute an upper bound for the implementation of trade adjustment measures aimed at reducing carbon leakage or maintaining competitiveness. In Fig. 2.2, we show the sectoral changes in the leakage rate and self-sufficiency (share of import on sectoral supply) for the Annex I countries as a whole compared with the baseline. As we expect, for coal, gas and energy-intensive sectors, the

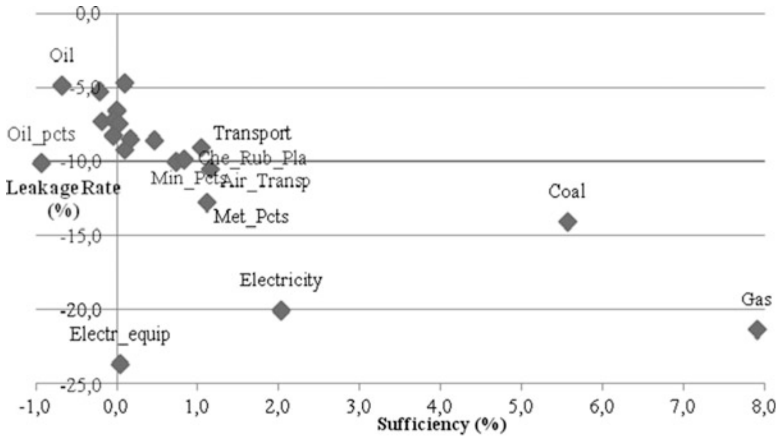


Fig. 2.2 Leakage rate and sufficiency for Annex I countries in ET scenario (compared with 2012 baseline)

share of import on total output increases due to domestic efforts to comply with the Kyoto Protocol.

Focusing on two major players such as the EU and the USA (Fig. 2.3), most sectors show a reduction in domestic production compensated by a surge in imports from non-abating countries. Results for this scenario clearly show the relocation of production from Annex I to non-Annex countries, highlighting the link between environmental policies and competitiveness effects.

Let us now start to analyse the non-cooperative solutions to carbon leakage, according to which an Annex I country adopts unilateral trade adjustment policies. Following Fig. 2.1 , we first compare the two scenarios, ET-NBAT and ET-BAT, simulating exogenous carbon tariffs based on permits equilibrium price. According to our results, the introduction of a CBT is welfare improving for compliant countries with respect to the reference case. In particular, CBTs improve the terms of trade for Annex I countries. By contrast, non-Annex countries register a welfare loss. The welfare improvement in Annex I countries is higher in the ET-NBAT scenario where the carbon content used to define the carbon tariff is related to the exporting countries (and for this reason, tariffs are higher than in ET-BAT).

The allocation of emission reductions across Annex I countries hardly changes by applying an exogenous CBT. By contrast, the introduction of tariffs affects emissions from non-Annex countries. In particular, the ET-NBAT scenario reveals a larger impact in terms of leakage reduction, especially for energy exporters, China, India and South Africa. In any case, the environmental effectiveness of these unilateral policies seems to be rather small since, although carbon leakage is uniformly reduced across all non-Annex countries, the overall change is trivial (especially in the ET-BAT scenario). This result can be explained by looking at the share of emissions related to exports by non-Annex towards Annex I countries. If we compare the amount of emissions associated with exports for each non-Annex

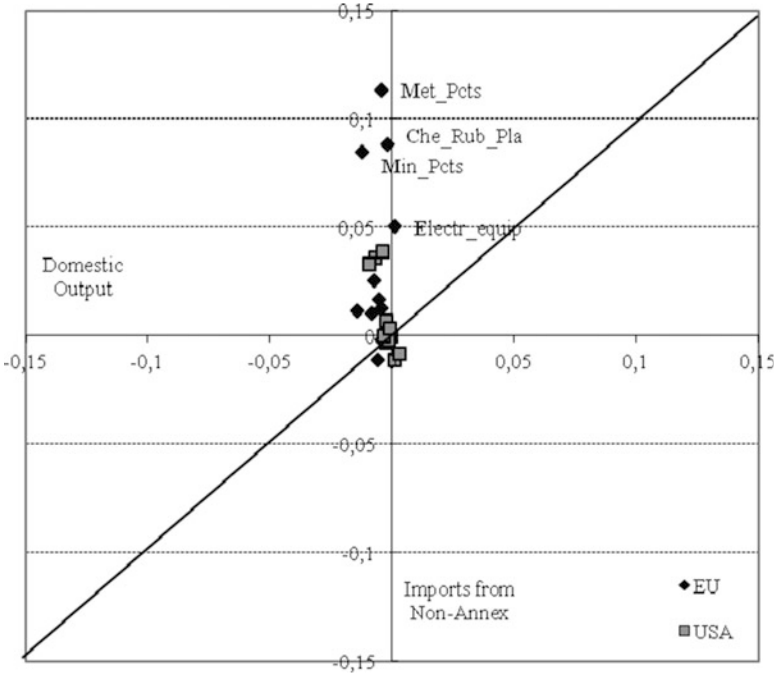
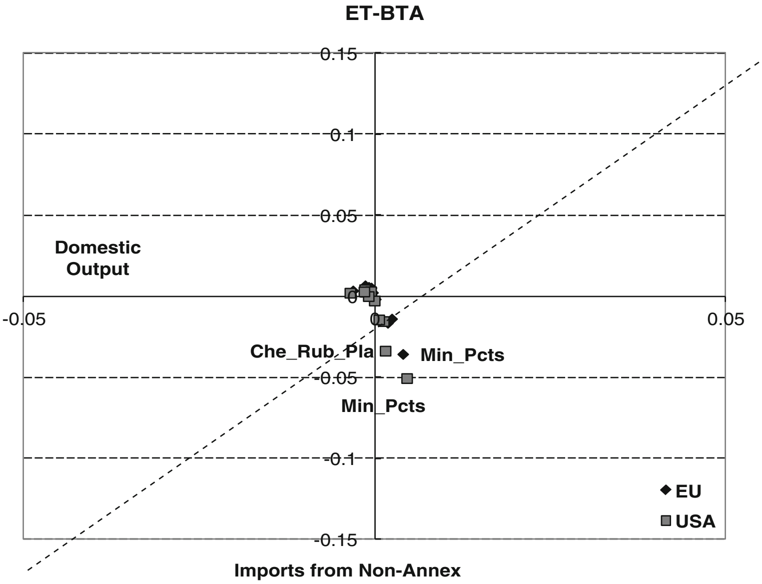


Fig. 2.3 The EU and US changes in domestic output and imports from non-Annex countries in ET scenario (compared with 2012 baseline)

countries to the Annex I group in the ET scenario with the total amount of emissions produced by firms in non-abating countries, the share of emissions influenced by the CBT is rather low and is even lower if we compare it with total non-Annex emissions. Accordingly, CBTs result in a pure redistribution of unilateral climate change policies costs, without substantial gains in environmental terms.

For the EU and the USA, the two most affected Annex I countries (representative also of seller and buyer behaviours), we then relate changes in domestic output to changes in imports from non-Annex countries maintaining the ET scenario as the baseline. The EU and US domestic production is hardly affected by the CBT when the domestic carbon content is considered (ET-BAT). On the other hand, both countries' outputs take advantage of the larger import reductions due to the higher tariffs when the carbon content of non-Annex countries is considered (ET-NBAT), especially in energy-intensive sectors (Fig. 2.4).

In the second set of scenarios, carbon tariffs are endogenously determined in order to keep the CO_2 emissions of all economic sectors (excluding households) in non-Annex countries (scenario ET-CL) and the share of imports in total production in Annex I countries (scenario ET-IO) unchanged. In both scenarios, the allocation of emission reduction in Annex I countries is not affected. The ET-CL scenario guarantees the lowest rate of carbon leakage among non-cooperative scenarios, although it is only halved since, for the reasons explained in Sect. 2.3, it cannot be



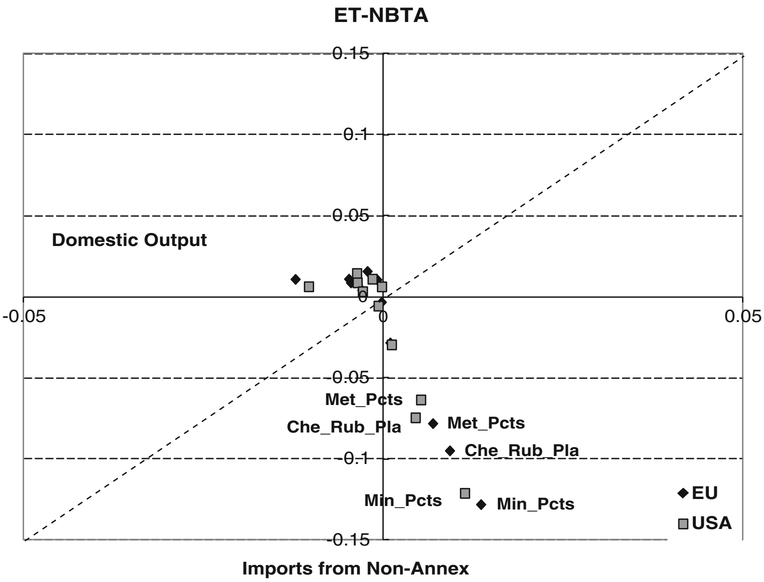


Fig. 2.4 The EU and US changes in domestic output and imports from non-Annex countries in ET-BAT and ET-NBAT scenarios

eliminated. In particular, some countries, such as China, India, South Africa and Rest of Europe, substantially reduce their emissions, and the contraction of their industrial sector is associated with high welfare losses. In this respect, the higher tariffs of this scenario also lead to very large terms of trade gains for Annex I countries.

On the other hand, the ET-IO scenario leads to emissions reduction in non-Annex countries which is similar to the outcome of the exogenous CBTs scenarios. The same is true for welfare impacts.

Looking at the relationship between output and import changes in the EU and the USA, Fig. 2.5 shows that the ET-CL scenario features larger reductions than the ET scenario not only for imports but also for domestic supply. It is also worth noting that in the ET-IO scenario, imports only decrease (with respect to the ET scenario) for some energy-intensive sectors and even increase in other cases, especially in the EU market.

If we compare the *ad valorem* carbon tariffs for alternative scenarios (Table 2.1), it is worth noting that tariffs needed to significantly reduce the carbon leakage problem (ET-CL scenario) are much higher than those currently discussed in the political debate (ET-BAT and ET-NBAT scenarios). It is interesting to note that carbon tariffs aimed at keeping the share of imports from non-Annex countries constant are higher in the energy-intensive sectors. The carbon tariffs in ET-IO scenario – even if not explicitly focused on carbon leakage – imply similar results to the exogenous tariffs based on the carbon content. With regard to non-Annex countries, ET-NBAT and ET-CL scenarios are characterized by higher changes in all sectors which explain their larger welfare costs.

From the Annex I countries point of view, in Table 2.2, we compare changes in the revealed comparative advantage (RCA) index (Balassa 1965) implied by the four different scenarios.

An interesting pattern emerges: the lowest protection scenario (ET-BAT) turns out to be the most effective in improving export competitiveness since it is associated with the highest number of positive RCA changes, meaning that competitiveness compared with the rest of the world is increasing in as many sectors as the number of RCA changes. This confirms that levying high tariffs on manufacturing goods which are intensively used as intermediates in domestic production has a significant negative impact on production costs and consequently on competitiveness.

Finally, we simulate a cooperative scenario in order to obtain a benchmark for comparison with the other results (Table 2.3). In the cooperative scenario, the carbon leakage problem is solved by definition since non-Annex countries are committed to keeping their emissions constant in relation to the 2012 baseline. Moreover, in this scenario, we also observe a much higher global emission reduction since all countries participate in emission trading and non-Annex countries have lower abatement costs. Looking at welfare changes for the world as a whole, our results clearly show that global welfare decreases when CBTs are introduced, as is to be expected, due to the negative impacts on allocative efficiency.

The cooperative scenario would constitute the best solution since welfare changes are more than halved compared with the scenario with emission trading (ET) and almost five times smaller than the scenario designed to partially eliminate carbon leakage through unilateral policies (ET-CL). By looking at the permits equilibrium price, we can shed some light on CBT effects. All scenarios featuring CBTs lead to an increase, albeit rather small, in the price of permits. CBTs protect

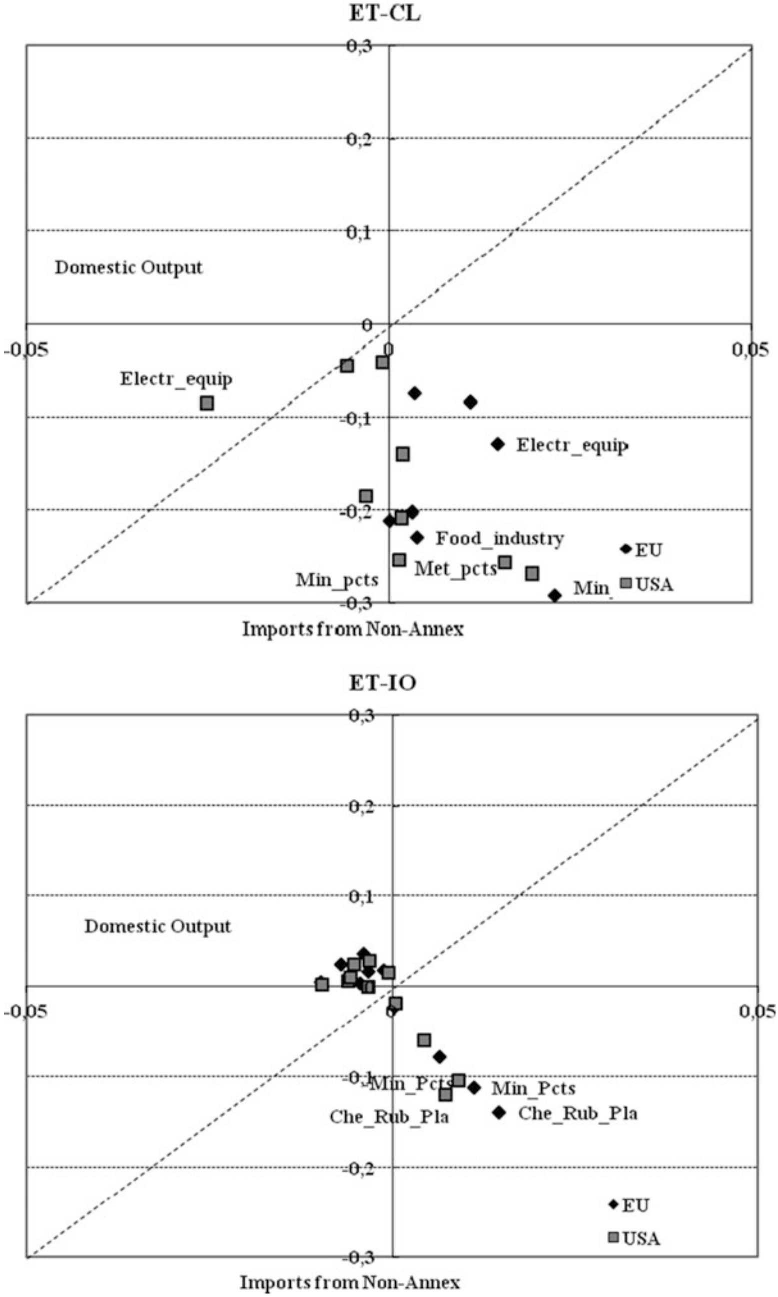


Fig. 2.5 The EU and US changes in domestic output and imports from non-Annex countries in ET-CL and ET-IO scenario

Table 2.1 Ad valorem carbon tariffs for alternative scenarios

	ET-BAT	ET-NBAT	ET-CL	ET-IO
Agriculture	1.11	1.15	21.42	0.36
Chem., rubb., plast.	0.71	2.15	14.47	3.32
Metal products	0.62	1.97	14.40	2.10
Mineral products	1.87	5.13	19.42	4.79
Oil products	1.03	2.90	8.12	8.78
Paper products	0.38	1.10	10.68	0.98
Average energy-intensive sectors	0.92	2.65	13.42	3.99
Electrical equipment	0.04	0.12	9.60	0.37
Food industry	0.23	0.33	14.30	0.16
Machinery equipment	0.07	0.29	12.54	0.52
Motor vehicles[a]	0.05	0.11	11.14	−0.14
Other manufacturing	0.08	0.69	8.27	0.33
Textile and leather	0.14	0.41	8.81	0.33
Transport equipment	0.06	0.28	12.80	0.21
Average other sectors	0.10	0.32	11.07	0.25
Total average	0.49	1.28	12.77	1.70

[a]In the ET-IO, no CBT are requested for this sector in order to comply with the condition of the scenario

Table 2.2 Changes in RCA for the EU and the USA in alternative scenarios

	EU				USA			
	ET-BAT	ET-NBAT	ET-CL	ET-IO	ET-BAT	ET-NBAT	ET-CL	ET-IO
Agriculture	0.12	−0.01	0.12	−0.01	−0.20	0.15	0.70	0.06
Oil products	0.09	0.12	−0.03	0.09	0.11	0.03	−0.07	0.01
Mineral products	0.13	0.11	0.10	0.12	0.08	0.02	0.02	0.02
Chem., rubb., plast.	0.41	0.25	0.10	0.21	0.11	−0.01	−0.09	−0.02
Electrical equipment	0.01	−0.01	0.01	−0.01	−0.36	−0.05	0.05	−0.04
Transport equipment	−0.07	−0.12	0.02	−0.10	0.79	0.13	0.54	0.16
Machinery equipment	−0.01	−0.06	0.14	−0.05	0.17	0.12	0.36	0.13
Motor vehicles	0.12	−0.07	−0.14	−0.06	0.30	0.02	−0.03	0.02
Metal products	0.23	0.09	0.11	0.10	0.01	0.01	0.03	0.02
Food industry	0.05	−0.11	−0.01	−0.11	−0.02	−0.02	0.00	−0.02
Paper products	0.08	0,01	−0.01	0.01	0.05	−0.01	−0.01	−0.01
Textile and leather	0.02	−0.04	−0.02	−0.03	−0.07	−0.01	−0.01	−0.01
Other manufacturing	−0.02	−0.04	−0.03	−0.03	0.01	−0.01	0.00	−0.01
Number of sectors with positive RCA changes respect with KT scenario	10	5	7	5	9	7	7	7

the domestic production of carbon-intensive sectors which increases the cost of reaching a given overall abatement target, resulting in larger welfare losses.

Table 2.4 shows the impacts of the carbon tax resulting from the global emission trading on energy product prices in selected sectors and countries. Impacts in non-Annex countries are higher than in Annex I countries since in this scenario, the first

Table 2.3 Comparing results with a cooperative solution

	ET-BAT	ET-NBAT	ET-CL	ET-IO	ET-GLOB
CO_2 reduction (%)	−5.70	−5.82	−6.09	−5.80	−6.54
Leakage rate (%)	12.91	11.09	6.95	11.43	0.00
CO_2 permits price (US$ per ton of CO_2)	23.15	23.31	24.60	23.17	8.44
Welfare change (million of US$)	−54.235	−55.435	−100.617	−56.074	−20.952

Table 2.4 Carbon tax average price impacts in selected countries with a cooperative solution

	EU	USA	Japan	FSU	Rest of Annex I	China	India	Energy exporters	Rest of non-Annex
Agriculture	49.78	19.59	12.82	32.78	16.90	34.29	58.35	66.49	26.33
Chem., rubb., plast.	22.64	21.32	19.51	27.27	19.24	42.92	28.23	27.68	22.61
Electricity	23.79	24.88	19.48	33.40	24.40	39.50	35.69	34.57	27.37
Metal products	35.86	22.71	19.46	32.98	22.94	45.75	31.95	32.81	25.93
Mineral products	26.44	22.42	19.21	32.22	23.76	46.43	32.77	31.37	25.43
Oil products	17.13	9.98	0.29	29.12	15.43	73.45	14.68	21.29	18.09
Paper products	28.89	21.55	39.49	34.28	21.20	49.56	31.99	31.55	27.58
Electrical equipment	72.79	24.02	24.89	38.18	24.33	75.91	37.93	55.05	31.35
Food industry	30.60	22.82	16.86	35.87	22.78	47.78	38.82	32.34	28.36
Machinery equipment	31.05	22.63	17.61	35.29	21.32	53.69	41.98	17.42	24.90
Motor vehicles	34.20	23.46	26.07	34.74	21.76	59.50	41.92	33.07	26.92
Textile and leather	31.17	21.63	14.04	35.23	20.36	51.33	32.15	32.69	24.95
Transport equipment	27.93	23.71	29.23	32.86	24.04	32.23	40.53	29.97	25.07
Other manufacturing	56.62	22.72	29.07	35.09	23.93	45.51	32.96	31.80	27.48
Average	*34.92*	*21.68*	*20.57*	*33.52*	*21.60*	*49.85*	*35.71*	*34.15*	*25.88*

group of countries accounts for a large share of emission reductions. Industrial sectors in China are subject to the highest increase in prices. The impacts of emission trading on prices are relatively high also in the EU and FSU, the Annex I countries in which the greater emission reductions take place.

The distribution of welfare changes in the cooperative scenario reveals that Annex I countries significantly reduce their allocative efficiency losses compared with the ET scenario. The price for this positive pattern is the cost of the emission permits that Annex I countries need to buy on the market. Non-Annex countries face opposite effects since they lose in terms of allocative efficiency, but as net sellers, they gain revenue from the permits sold. More importantly, allocative efficiency gains for Annex I countries are much larger than the allocative efficiency losses for non-Annex countries (Table 2.5). At country level, not all non-Annex countries will gain from participating in a global solution where big gainers are China and energy exporters and big losers are India and Rest of Europe.

Table 2.5 Distribution of welfare impacts in a cooperative solution

	ET				ET-GLOB			
	Permits revenue	Allocative efficiency	Terms of trade	Total welfare change	Permits revenue	Allocative efficiency	Terms of trade	Total welfare change
Australia	−1.147	−1.834	−1.026	−4.151	−822	−458	−1.313	−2.694
Belarus	152	528	373	1.085	21	232	195	462
Canada	−1.873	−2.487	−984	−5.391	−1.088	−612	−362	−2.193
Croatia	−8	−75	49	−23	−12	0	21	20
EU	5.197	−17.243	11.639	−683	−228	−1.989	5.800	3.194
FSU	9.755	−7.735	−3.036	1.806	1.377	−2.071	−2.544	−2.097
Japan	−985	−4.159	5.322	−387	−976	−305	4.489	2.475
New Zealand	−155	−115	72	−205	−77	−24	26	−90
Norway	−289	−289	−2.707	−2.876	−126	−72	−1.486	−1.574
Swiss	−3	−422	399	−203	−40	−84	270	−20
USA	−10.521	−20.937	6.545	−25.089	−8.592	−5.193	3.627	−9.527
Annex I	*124*	*−54.769*	*16.650*	*−36.118*	*−10.563*	*−10.575*	*8.723*	*−12.044*
Brazil	0	237	355	344	109	−254	558	289
China	0	−149	1.885	−14	6.081	−2.994	1.446	3.840
India	0	697	1.014	1.854	1.196	−1.413	1.242	838
Mexico	0	−960	−1.482	−2.496	130	−1.703	−657	−2.292
South Africa	0	97	2	78	803	−488	36	348
ENEEXP	0	−305	−22.484	−21.969	1.461	−2.347	−16.763	−16.299
Rest of Africa	0	−4	−258	−171	56	−126	−184	−209
Rest of America	0	104	348	359	120	−253	519	319
Rest of Asia	0	1.205	3.572	3.851	515	−564	4.621	3.874
Rest of Europe	0	403	232	829	117	−211	403	385
Non-Annex	*0*	*1.325*	*−16.817*	*−17.334*	*10.587*	*−10.354*	*−8.779*	*−8.908*
Total	*124*	*−53.445*	*−167*	*−53.452*	*24*	*−20.929*	*−56*	*−20.952*

2.5 Conclusions

In this chapter, we propose alternative border tax adjustments for dealing with carbon leakage. We simulate different scenarios to gain a better understanding of to what extent a border tax is effective in reducing the leakage rate and if major differences emerge when alternative CBTs are modelled. More specifically, we are interested in investigating the impact in terms of leakage reduction and to what extent such trade policies are also a valid instrument for protecting the economic competitiveness of compliant countries in the international market.

From our results, we can affirm that the effectiveness of CBTs in reducing carbon leakage is limited and that they could even be damaging in terms of competitiveness when CBTs act on prices of goods produced by non-abating countries and are used as intermediates in abating countries. Moreover, border tariff adjustment feasibility with respect to WTO rules is a moot point, and justifying them with climate concerns could open the way to a proliferation of highly distortive unilateral measures.

When comparing CBT effectiveness with a global cooperative scenario, our results clearly suggest that a cooperative solution would be highly preferable both in terms of welfare impacts and allocative efficiency in emission reduction. In fact, the cooperative solution is welfare improving with respect to all CBT forms. This last point suggests that the bargaining power exerted by Annex I countries in the post-Kyoto agreement should be directed towards a global solution including major emerging economies in the policymaking process rather than towards unilateral solutions in which a domestically oriented point of view prevails.

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