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BORDER TAX ADJUSTMENT: A FEASIBLE WAY TO SUPPORT STRINGENT EMISSION TRADING

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BORDER TAX ADJUSTMENT: A FEASIBLE WAY TOSUPPORT STRINGENT EMISSION TRADING

ABSRACT: CO2 emission allowances help to internalise effects of fossil fuel consumption on global climate and sea levels. However, consumption, production and investment decisions do not reach the optimal allocation when the scheme is only implemented in some countries. Production with inefficient facilities in non-participating countries may even increase. Border tax adjustment for costs incurred from procuring CO2 emission allowances reduces the leakage. We show that border tax adjustment (BTA) can be both feasible and compatible with WTO constraints. Practicable implementability requires a focus on CO2 emissions from certain processed materials and a separate treatment of electric energy input.

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The leading industrial and developing countries are in principle committed to contributing their fair share to tackle climate change in order to stabilize greenhouse gas concentrations at a level that would prevent dangerous anthropogenic interference with the climate system (G8 summary statement, 2007). To deliver these emissions reductions a mix of three types of policies have to be implemented at regional and national level (i) technology policy (ii) evolving institutional and regulatory frameworks (iii) internalisation of CO2 costs.

Countries and regions might vary their emphasis between different instruments, so as to reduce emissions most effectively in their specific political, economic and social situation. Retaining this flexibility for the national implementation facilitates negotiations on a comprehensive agreement within the United Nations Framework Convention on Climate Change.

The flexibility to choose the balance between policy instruments can imply that countries initially pursue independent trading schemes or CO_2 taxation approaches. For a transition period this is likely to result in different CO_2 prices across regions and can have three effects:

First, regions with low CO_2 price levels delay investment in some emission abatement that is cheaper than some of the investment that is pursued in regions with high CO_2 price levels. This static inefficiency might be partially compensated by dynamic benefits – high CO_2 price levels give incentives for the development and diffusion of low Carbon technologies. We will not discuss this effect further here, and only note that instruments like the clean development mechanism or funds to avoid deforestation suggest that some lower cost abatement options can be realised even where CO_2 price levels differ.

Second, persistent CO_2 price differences influence corporate decisions on investment, operation and closure of plants for the production of CO_2 intensive commodities. Local emission reductions could result from relocating rather than from improvements of production of cement, semi-finished steel or basic chemicals. Leakage reduces the environmental effectiveness and creates strong political opposition in sectors where jobs, tax revenue and profits are at risk.

Third, currently discussed emission reduction targets of 50% to 80% in industrialised countries are unlikely to be delivered by improving individual production processes. They require substitution towards less CO_2 intensive intermediary and final products. Where CO_2 externality costs of production are reflected in prices, firms and consumers can choose where and how to best substitute CO_2 intensive commodities and products. Elasticity estimates for cement of the range of 0.46 for the short run and 1.47 for the long run (Roller and Steen 2005) and for steel 1.37 (Hekman, 1978) illustrate that demand responsiveness may be significant and can therefore contribute to emissions reduction. However, competition and trade with regions where CO_2 prices are lower can prevent the full pass through of CO_2 costs and weaken the substitution effect.

Figure 1 illustrates that already modest CO2 prices of 15 Euro/t CO2 could for some sectors result in cost increases that exceed 5% of the sector's net value added. Analysis of sub-sectors and production processes points to specific sub-sectors that are exposed – and commodities like semi-finished steel, clinker, cement and some basic chemicals where relative cost increases are particularly high.

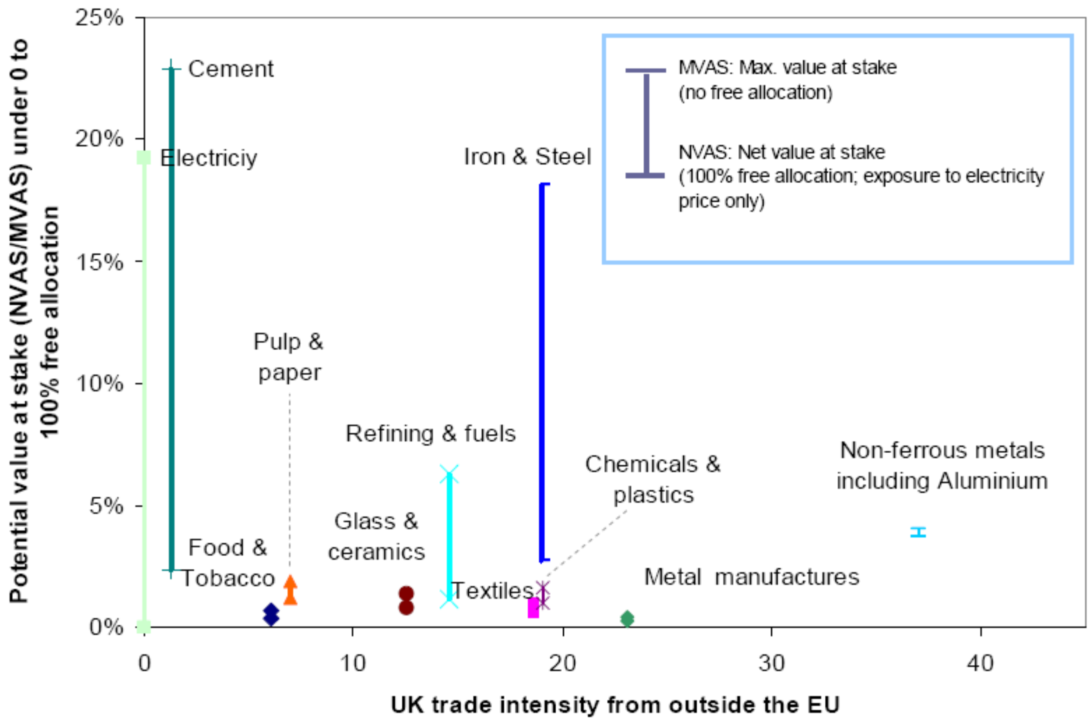

Figure 1 Net Value at Stake relative to UK trade intensity from outside the EU (Grubb and Neuhoff 2006)

The risk of leaking emissions and jobs, profits and tax revenue for these sub-sectors can induce three types of policy responses.

First, regional emission trading schemes in the US focus on the power sector and exclude sectors where leakage could have strong impacts.

Second, European member states subsidise investment in new Carbon intensive production with free allowance allocation and penalise closure by withdrawing allowances. While addressing some leakage concerns, such contingent, and usually repeated, free allowance allocation creates economic incentives and administrative constraints that create significant economic inefficiencies.

Third, discussions about the possibility to exclude sectors from the scheme or to relax the overall scheme can create uncertainty as to whether future CO_2 prices will be robust. Risks of low CO_2 prices increase the investment risk for low Carbon projects, and can delay or reduce the volume of investment.

Any of these options reduce the environmental effectiveness of ETS. Hence, we take a closer look on border tax adjustment (BTA) as another often-mentioned instrument to address leakage concerns. (e.g. Azar, 2005; Biermann and Brohm, 2003; de Cendra, 2006; Demailly and Quirion, 2005; Esty, 1994; Goh, 2004; Mathiesen and Mæstad, 2004; Zhong, 1998; generally on BTA Hufbauer, 1996). BTA would allow countries to abolish free allocation, with all its implied distortions, without risking leakage. The principle of border-tax adjustment is that a charge is imposed on imported products into the country that is equal to the charges payable when producing in that country. Exporters from that country get a refund on the CO2 charges they incurred during production in the country.[2]

Three concerns are typically raised against BTA:

- legality; in particular the legality under world trade law is questioned (Goh, 2004);

- economic efficiency and transaction costs (on the latter cf. Crals and Vereeck, 2005);

- political implications

In our paper we propose a straw man to address these concerns, namely border tax adjustment (BTA) with Best Available Technology (BAT) for basic materials including electricity.

According to our analysis, the proposed scheme should be compatible with World Trade Organization (WTO) laws. The compliance comes at a price, however: as already indicated, the adjustment is made for the costs of allowances corresponding to production with BAT rather than average technology. As Demailly and Quirion (2005) have shown for the case of the cement industry by using a partial equilibrium calculation, leakage is not necessarily significantly increased by adjusting at BAT level rather than at actual emissions level; furthermore, only basic materials, but not subsequent production steps are adjusted for. For electricity input, slightly different rules apply.

In order to minimize transaction costs, for simplicity we focus on basic commodities and avoid a process-oriented mechanism. As for the basic commodities, the cost increase from CO2 allowances relative to value added in the production step is highest and this is where the concern about leakage lies.

The political dimension of the implementation of border tax adjustment is likely to be the most critical aspect for a successful implementation. After all, international negotiations aim to ensure countries cooperate on reducing emissions – and the cooperative approach should not be undermined by a perceived implementation of trade barriers. This paper does not assess the political aspects of border tax adjustment, but we hope to offer a starting point for such discussions

2 Such a system is currently in force for VAT. For example, an Austrian resident who travels to Switzerland and buys a computer there must pay Swiss VAT on the purchase. When he returns to Austria he can claim a reimbursement of Swiss VAT, but will have to pay Austrian import tax at a rate equal to that of Austrian VAT. Hence, his decision where to buy should be unaffected by differences in VAT between the countries.

by showing that the combination of BTA with CO_2 price internalisation does not discriminate against foreign producers.

The proposal builds on the seminal work on border tax adjustments and their compatibility with WTO law which Hufbauer (1996) has undertaken in the context of a transition to a tax system placing more weight on taxing consumption rather than income. In much of the existing literature, BTA has at best received lukewarm responses (see Esty, p.168 on a proposed introduction of US BTA; Goh, 2004; Zhong, 1998). In particular, the need to identify the appropriate carbon contents embodied in traded goods where exporting countries are unwilling to cooperate in the certification of production methods has been considered as an insurmountable hurdle (Zhong, 1998). In contrast, the paper shows that BTA can be a feasible and practicable way to implement a level playing field. It finds best available technology as a WTO law compatible method for calculating border tax adjustments.

To simplify the presentation of the analysis in the paper, we only discuss the case with one region covered by emission trading while other regions have not implemented CO2 pricing. This directly translates to the case where different countries or regions have implemented CO_2 pricing at different levels. Like in the case of value added tax, exports from one region receive an export compensation based on the CO_2 price level in the exporting region and pay an import tariff corresponding to CO_2 price level in the importing region.

The paper contains the following sections: Section two shows how BTA can mitigate the productive and allocative inefficiencies of implementing emission allowances only in one region; Section three analyses the restrictions under international law and, in particular, GATT; Section four addresses practical questions concerning implementation; and Section five concludes.

1 The Economic Case for BTA

Most agents do not sufficiently weigh the change in global climate induced by their CO_2 emissions and the resulting adverse effects for humankind as a whole. They are therefore likely to cause and in turn to suffer from excessive emissions. The requirement to buy and present allowances for CO_2 emissions internalises this negative externality and provides for more efficient production and consumption decisions. However, uncertainty about future costs and political lobbying by groups who anticipate losing from the tax hamper this internalisation. As a result, countries might pursue price internalisation at different levels of stringency reflected in different CO_2 prices. In particular we assess a situation where only one region implements emissions trading. This raises the questions whether such partial implementation reduces the effectiveness of the scheme and, if so, whether BTA can restore some of the efficiency gains.

The first question can be answered in the affirmative. This can be shown with the assistance of a simple model. Let there be one product and two regions. In one region – which we will call B –, an emissions trading scheme is implemented. In the other region A, the scheme is as to yet absent. Except for the emissions trading scheme, the regulatory environment in both regions is assumed to be equal. Demand and supply are perfectly competitive in both regions. Trade of the product between these regions is costless and arbitrage is feasible. Production, trade and consumption occur simultaneously. Without BTA, prices are therefore equal in both regions.

1.1 Static analysis

As a first step, we present a static analysis assessing the utilisation of existing production facilities. The static analysis ignores learning externalities as well as uncertainty about future facilities and emission targets. Assume a distribution of existing production facilities, where facilities differ only in the amount of energy required to produce one unit of the product. For ease of exposition, further assume that the distributions of facilities in the two regions are identical.

Global implementation of emission allowances brings about optimal production and consumption decisions. Production costs increase for all facilities, and the least efficient facilities, which require the most emission allowances, incur the highest rise. Consumers reduce demand as prices increase. Hence, the least efficient facilities cease to produce. The same mechanism applies in both regions. CO2 emission allowances therefore increase price and slightly reduce production in both regions relative to a scenario without emission allowances (Equations (3) and (4) in Appendix).

This no longer holds with **partial implementation without BTA**. What happens relative to a scenario without emission allowances when only region B introduces emissions allowances, just as it would under full implementation, while the region A does not implement allowances at all? Mæstad (1998) shows that this will result in global inefficiencies. In the appendix we develop an analytic model to asses the local impact on production and consumption in both regions. The model allows for inhomogeneous technologies in both regions. Production costs in region B increase, as producers must obtain emission allowances. The least efficient facilities in region B will cease to produce. The reduction in supply increases the price and lowers consumption in both regions, but by less than under the full implementation scenario (Proposition 3 in Appendix). At the same time, partial implementation yields inefficient production decisions. In region B, cost increases to the same level as under full implementation, whereas the price increases by a smaller amount. Thus, production in region B is even lower under partial than under full implementation. Not only inefficient but also some efficient facilities are squeezed out of the market (Proposition 1 in Appendix). This contrasts to region A, where higher prices at constant costs increase output and where even facilities which are inefficient under non-implementation will be used for production (Proposition 2 in Appendix). This can reduce part or potentially all of the welfare gains from the substitution effect away from Carbon intensive products.

Now assume **partial implementation with border tax adjustment (BTA) at the level of best available technology (BAT)**: When a product is imported into region B, the importer owes a tax equivalent to the costs or opportunity costs which a producer with BAT in region B incurs for emission allowances. Such a scheme may increase or decrease production in region A relative to no emission allowances, dependent on demand and facilities (Proposition 4 in Appendix).

This is the result of two countervailing effects. On the one hand, higher consumer prices in region B reduce region B’s and hence global demand – and with it equilibrium global production. If demand is very price-responsive in region B, then the global demand reduction is the dominant effect and producers in region A and region B will face lower output levels. On the other hand, producers in region B which do not produce with best available technology bear higher costs for the emission allowances than producers in region A pay for the BTA. Hence some of region B’s production might continue to be substituted by region A’s production. If dispersion of efficiencies between facilities is high, this effect dominates and production in region A is increased with BTA at BAT. This analysis is a special case of Grossman’s analysis of BTA (1980).

1.2 Dynamic Analysis

Now allow for investments adding new facilities to the distribution of facilities. All new facilities can employ the same technology. Assume investment costs rise as energy consumption in production falls. Investors thus face a trade-off between low investment costs coupled with high energy costs for inefficient machines and high investment costs for efficient facilities coupled with low energy costs. Further assume the absence of location-specific rents. Hence, there will generally be one optimal technology, depending on energy costs that will be used for all investments.

Under partial implementation without BTA, there will be no **investmen**t in region B. As a consequence of the assumption of costless trade, all investment takes place in region A. The new facilities will be slightly less energy-efficient than they would have been in region B, where CO2 emission allowances would have shifted the balance towards a more energy-efficient technology. Hence allowance trading in region B without BTA will – in our simple model – not achieve the dynamically efficient technology choice for new facilities.

If BTA compensates for the allowance costs of a producer with best available technology, then in first order, investors are indifferent about whether to invest in region B or region A. In second order, the CO2 allowance costs in region B induce investors to choose a technology with slightly lower emissions, accepting a trade-off of slightly higher costs for other input factors. Thus, even as BTA compensates region B's investors for costs of CO2 allowances in international competition, their constrained optimisation implies that they face slightly higher costs of production than in region A.

One challenge of BTA is to set an appropriate level of tax. To achieve dynamic efficiency, it has to be ensured that individual firms, by building a more efficient facility in region B, do not define a new BAT. Otherwise the firm might be reluctant to invest in this facility, as the new BAT would reduce the level of BTA and thereby lower the price the firm would receive for its products in region B. The issue can be avoided if BAT requires a certain market share of the technology and covers several related products, so that any individual company decision is marginal.

2 WTO/GATT Law as a Restriction of the Policy Space

Obligations under international law restrict the policy space. The most relevant restriction for the proposed scheme of BTA comes from WTO/GATT (Demaret/Stewardson, 1994; Petersmann, 2000). Any breach of these obligations can lead to a dispute settlement procedure which can ultimately give the applicant state permission to impose trade sanctions on imports from the infringing state until the other state ceases its infraction. If it is unclear whether the BTA scheme is GATT compatible and therefore sustainable, future revenues from energy-intensive production plants are risky and investors are unlikely to choose efficient technologies and plant locations. Possible incompatibilities with GATT should therefore be avoided. In the following, we examine potential conflicts of BTA with GATT.

For legal purposes, the BTA described in the previous section amount to two different measures which follow a distinct regime. Refunds for exports must not be an outlawed subsidy, whereas taxes charged on imports must not represent an illegal discrimination. Since, legally, the criteria need not necessarily be the same (Fauchald, 1998), both measures will be analysed separately.

2.1 Exports

Under WTO law, countries must not subsidise most forms of exports (Art. XVI:4 GATT). If prohibited subsidies are granted, the importing state may, under conditions spelt out in Art. VI:3 and 6 (a) GATT, impose countervailing duties on the imported goods. However, Art. VI:4 GATT makes it clear that a countervailing duty may not be implemented where a product destined for export is exempted from duties or taxes borne by the like product when destined for consumption in the region of origin or exportation, or such duties or taxes are refunded on exportation. In the same vein, under the Note ad Art. XVI, these exemptions or remissions do not constitute subsidies under that article.

The 1994 Agreement on Subsidies and Countervailing Measures extends the range of adjustable prior-stage cumulative taxes under GATT. Annex I to the agreement contains an illustrative list of prohibited export subsidies. Litera (h) allows a region to remit taxes in respect of prior stages of cumulative taxes on inputs that are consumed in the production of the exported product, making normal allowances for waste. Footnote 61 to Annex II specifies inputs consumed not only as inputs physically incorporated, but also as energy, fuels and oils used in the production process and catalysts which are consumed in the course of their use to obtain the exported product.

Consequently, it appears that *tax* exemptions and remissions for energy and fuel on exported products would be admissible under WTO rules. From this, it does not automatically follow, admittedly, that any costs for *allowances* should be deductible as well. Yet the GATT mentions duties alongside taxes, e.g. in Art VI:4. Generally, taxes can be defined as a compulsory contribution imposed by government for which taxpayers receive nothing identifiable in return for their contribution (Ismer and Sailer, 2003; Lang, 2005). Defining duties in the same vein would require there is at least a compulsory payment made to the state. In order to prevent abuse, it cannot include payments to the government made in return for a more or less specific service. Also, a fee for using a motorway or, more controversially, a fee for a broadcasting license would probably not be included. In all these cases, the service given to the individual already compensates him for the costs incurred. The same, however, is not true for the right to emit CO_2. In the case of motorways, the individual gets a service that did not exist before the government provided the infrastructure. The necessity of an allowance for emitting CO_2 almost exclusively serves the interests of the wider community. Hence, the costs of obtaining the allowances should not be seen as providing such a service. If only a fraction of the allowances are bought from the state, then the costs of buying the allowances should be spread over all the allowances. Only these can be remitted.

If half of the allowances in circulation were allocated to each business free of charge and the second half had to be bought for a price of 100, the price used for adjustment purposes would be 50. If the average costs incurred by firms for CO_2 allowance were used to calculate BTA tariffs, then the effectiveness of BTA would be reduced with free allowance allocation.

Alternatively, one could argue that the issuance of allowances to firms is a lump-sum transfer and should therefore not affect the calculation of average costs of CO_2 allowances. However, even provided these lump sum transfers did not run afoul of WTO subsidy rules, the legal terminology which speaks of duties and links them to taxes might prevent this interpretation.

A second question is how to measure the ‘content’ of CO_2 allowances attributed to a product: should it be based on volume, weight or value, to best relate it to the input components? A general solution seems to be warranted, for the quantity of emissions can hardly be ascertained for a specific item and even where it could, it would imply that for all exports the incentive to produce with the least amount of greenhouse gas emissions would be eliminated. Therefore, exported products should receive the same remission irrespective of how they were actually produced. Regarding the level of tax remitted, it should be borne in mind that there is the danger of the remission turning into an illegal subsidy, distorting the playing field. Hence, the amount should be fixed at a rather conservative (i.e. low) level. This issue will be further discussed, in section 2.3, once the import side has been discussed.

2.2 Imports

Since BTA on imports cannot qualify as quantitative restrictions outlawed under Art. XI GATT, two major requirements must be met under GATT. First, WTO member states are obliged to offer every other member state most favoured nation status with respect to any border restrictions (Art. I GATT). Secondly, Art. III GATT stipulates that foreign producers be treated with no less advantageous terms than domestic producers (national treatment clause). This applies to like products (Art. III:2 first sentence GATT) and to directly competitive and substitutable products (Art. III:2 second sentence).

2.2.1 Art. III:2 first sentence GATT: Non-discrimination against “like products”

According to Art. III:2 first sentence GATT, member states shall not subject imported products, directly or indirectly, to internal taxes or other internal charges of any kind in excess of those applied, directly or indirectly to like domestic products. In accordance with WTO case law (Japan – Alcohol, p. 18; see also Hufbauer, 1996 and de Cendra, 2006), we will first discuss the definition of like product, then of the calculation of charges applied for imported and domestic products and, finally, the interpretation of ‘excess’ in the legal context.

GATT itself does not define the term ‘like product’. WTO case law suggests that the term has different meanings in different articles (European Community – Asbestos, para. 99). Consequently, proponents of an “aims and effects test” argue that any attempt to define likeness would be inappropriate (Mattoo and Subramanian, 1998). Rather, any distinction made on regulatory grounds should be allowed. Only where the distinction was inspired by protectionist intent or where a protectionist effect followed from it, would it contravene Art. III:2 first sentence GATT. Such “aims and effects” test can imply that physically identical products with different production processes are no longer like products (Biermann and Brohm, 2003; Howse and Regan, 2000). The WTO judiciary (European Union – Bananas para. 241; Doelle, 2004) has explicitly rejected this test. Rather, it has adopted a different stance. Likeness is assessed taking into account physical properties, the product’s properties, nature and quality, its end-uses in a given market, consumers´ tastes and habits, as well as the tariff classification of the product (Japan – Alcohol, p. 20). Production processes that do not change the physical properties, etc., of the product are considered to be irrelevant. In particular, it will be assumed that consumers’ tastes and habits do not overcome the “strong presumption of likeness [for physically identical products]” (Quick and Lau, 2003; Goh, 2004). For both approaches, like products could probably be found in the case of BTA. Assuming that both foreign and domestic products were manufactured with a plenitude of technologies, the first-mentioned approach would have to consider products produced with a similar technology to be like, while the judiciary would have to consider the entire group of homogeneous products to be like. Hence, the criterion of like products would, under either approach, pose a surmountable hurdle. What taxes or charges are taken into account to determine the level of border tax adjustment? While it is clear that the imported product would be subject to the (border adjustment) tax, it is less clear which taxes and charges are applied to the domestic product. As it has been held in the US – Superfund Case (paras. 5.2.3 – 5.2.4), the reason for imposing the tax, i.e. whether the tax was levied to encourage the rational use of environmental resources or for general revenue purposes, is irrelevant. Furthermore, indirect taxes like a sales tax or a VAT are definitely taxes applied on the domestic product. BTA for these taxes are commonplace in practice (an example would be excise taxes on the import of goods), and can legally be so, as they are levied on foreign and domestic products alike. This is confirmed by Note Ad Art. III, which explicitly states that any internal tax or other internal charge which applies to an imported product and to the like domestic product, and is collected in the case of the imported product at the time or point of importation, is nevertheless to be regarded as an internal tax or other internal charge. In contrast, there is a widespread view that direct taxes, among them in particular taxes on profits, are not levied on the product and hence do not count for the tax burden on the domestic product (Demaret and Stewardson, 1994)). Thus, adjustments for direct taxes would be in breach of the GATT obligations. Therefore, the question arises on which side of the direct/indirect taxes dividing line the costs for emissions allowances would fall.

How would a tax on carbon emissions be classified in this context? Scholars are divided. Pitschas (1994) argues that Art. II: 2 (a) GATT[3] indicates energy taxes should not be viewed as a

3 Reading: “Nothing in this article shall prevent the parties from imposing on the importation of any product a charge equivalent to an internal tax imposed consistently with the provisions of paragraph 2 of Article III … in respect of an article from which the imported product has been manufactured in whole or in part.” The equally valid French text “une marchandise qui a été incorporée dans l’article importé” lends even more support to that view.

tax adjustable at the border. However, the wording does not indicate that the clause actually seeks to disallow tax adjustment at the border. In this case, the symmetric treatment of exports and imports could warrant border tax adjustment for imports (Demaret and Stewardson 1994), and therefore the results obtained for export BTA should equally apply to imports.

The wording in Art. I GATT uses the term “originating in or destined for” in a way that tends to support a symmetric treatment (Fauchald 1998). Furthermore, a symmetric treatment has the advantage of simplicity. It also ensures that the destination principle is applied as coherently and efficiently as possible, in order to avoid excessive trade distortion. Although member states do not have an obligation to make symmetric use of adjustments they are allowed to make, they should be given the possibility to avoid double taxation or double non-taxation (Demaret and Stewardson, 1994), each of which would disturb the level playing field among competitors which is vital for the welfare gains from international trade to be reaped.

We finally turn to the interpretation of ‘excessive’ charges. The criteria is only whether “like” imported products are subject to higher taxes, not whether this leads to a significant distortion in trade flows (Zarrilli, 2003), with references to WTO case law). In particular, it does not matter whether only a small percentage of domestic output profits from a lower tax rate (US – Malt Beverages). However, it does not appear warranted to include charges imposed by the country of origin, since the addressee of the prohibition contained in Art. 3:II first sentence GATT is only the importing state and not both states taken together (different view held by Goh, 2004).

Thus, if one followed the view that likeness must not be denied by taking into account production methods, all products must, regardless of how they were made, be considered as homogeneous. The only way to introduce BTA would then be to take the lowest charges incurred by any domestic producer. To make this practically feasible, the lowest amount should be estimated by assessing the quantity of greenhouse gases that would have been emitted when all components had been manufactured with BAT. This concept can be defined as, for example, the most effective and advanced stage in the development of activities and their methods of operations which indicate the practical suitability for providing in principle the basis for emission limit values designed to prevent and, where that is not practicable, generally to reduce emissions and the impact on the environment as a whole, as in the European Commission Council Directive 96/61/EC of 24 September 1996 Concerning Integrated Pollution Prevention and Control. It might be advisable to entrust the definition of the BAT standard to an independent body. This body is likely to receive all required information from industry, as foreign industry would want the standard to be the lowest possible, whereas domestic producers would want to see it high.

If, in contrast, one held the view that production processes are relevant for “likeness”, there would be as many different products as there were substitutable production processes. In the Panel Report on the US – Reformulated Gasoline Case (para. 6.14), the panel did not accept as a valid defense the fact that, on average, the treatment of foreign and domestic firms was equivalent. This is not contradicted by the US – Superfund Case where the GATT panel considered the method by the US, which imposed an adjusting tax amounting to what would have been payable under the predominant US production method, to be in accordance with GATT rules. Foreign producers had the possibility of establishing that less of the input in question was used and that the tax charged should thus be lower. This principle implies for BTA that Art. III:2 first sentence GATT is violated where the foreign producer does not have the possibility to show that its carbon emissions are lower than the standard assumed for adjustment, while domestic producers pay according to their true emissions. To avoid the issue, one could adopt an approach where each business must, upon importation, demonstrate how much greenhouse gas was emitted during production. This, however, seems even less desirable for imports than for exports. While the latter are subject to the control of the exporting state, the production of the former has taken place outside its jurisdiction. Because of the territoriality principle under public international law, any controls would, unless the other state consented, have to be carried out by officials of that other state, which might have little incentive to expose their industry to foreign taxation. Hence, the best technology approach would be allowed under Art. III:2 first sentence GATT. Indeed, if one shared the view of the judiciary, that production processes were irrelevant for likeness under that provision, this would constitute the only admissible way. If one did not, it would still be the only really feasible way. Further discussion of compatibility with Art. III:2 second sentence GATT and Art. I GATT will therefore concentrate on this approach.

2.2.2 Art. III:2 GATT: Nondiscrimination against directly competitive and substitutable products

Art. III: 2, second sentence GATT in conjunction with Art. III:1 GATT and the Note Ad Article III demands that imports not be taxed dissimilarly from directly competitive or substitutable domestic products in such a way as to protect domestic production. With respect to taxation, under WTO case law (Japan – Alcohol, p. 24; confirmed in Chile – Alcohol, para. 47), this raises two questions. First, are competing imported and domestic products not similarly taxed, a distinction which requires a difference that must be more than de minimis? And second: is the dissimilar taxation applied so as to afford protection to domestic production? This last question demands – diverging from Art. III: 2 first sentence GATT – that protective impact be ascertained separately.

Again, problems with this provision can be avoided when a BAT BTA is applied priced at the average price per allowance paid to the state. On the first question, it would, however, not be sufficient to argue that domestic products in the same fiscal class would be taxed or charged at a higher rate. Rather, a comprehensive approach must look at all the directly competitive or substitutable domestic and imported goods (Chile – Alcohol, para. 53). One might conceive a situation where mainly foreign highly energy-intensive goods directly compete with ("unlike" in the sense of Art. III:2 first sentence GATT) products made mainly domestically and with little energy input. Consider the following hypothetical example: most imported cars are aluminum cars and domestic cars are steel based. Both types of cars compete directly. Aluminum cars consume far more energy in production than steel cars. Hence, the implementation of BTA would mean that imported cars were generally taxed at a higher rate. The second question, of whether the measure affords domestic protection, would thus become pertinent for BTA, where the tax difference is less than *de minimis*. In view of the fact that members of the WTO have sovereign authority to determine the basis on which they will tax goods and to classify goods accordingly, provided they respect their WTO commitments, this could be safely denied. A dispute resolution board, which have to look at the design, the architecture and the revealing structure of the measure, would in the framework of a comprehensive and objective analysis, would find a linear tax-scheme. This is a significant contrast to the Chilean Alcohol Case where, due to their alcohol content, most imported products fell into a progressive zone (Chile – Alcohol, para. 63). This linearity would, moreover, be in harmony with the aim of CO2 abatement and with the (community-wide) emissions trading scheme. And finally, even though it appears possible that some mainly imported goods fall into a class viewed as high energy-intensive, it would seem a rather contrived example. However, in contrast to cases (Chile – Alcohol; Japan – Alcohol; Korea – Alcohol), where almost all imported products fell in the higher tax groups, it would not be the norm under BTA that imported goods fall into the higher taxed group.

2.2.3 Art. I GATT: Most Favoured Nation Principle

The system of BTA with BAT would not violate the most favoured nation principle of Art. I GATT, as the system would apply to any import regardless of whether the product is imported from a Kyoto member country or not. Also, just as under VAT, there would be no net taxes where imports are followed by exports of the same product, as the remission of taxes would follow the same standard.

2.3 Interim Conclusion

It has been demonstrated that a system of BTA for imports with BAT standards priced at average costs would not violate the GATT. It has further been shown that subsidies ought to follow a general standard of BAT. It would therefore seem logical to extend the proposal from imports to exports as well. Again, this would not be interpreted as a subsidy, as it would only remit the minimum of internal charges incurred by domestic producers.

2.4 Auxiliary Point: Justification under Art. XX GATT

If a scheme is not in compliance with Art. III or I GATT, protection of a common good (Art. III: 2 GATT, Art. XX GATT) may provide a justification. The body of case law on world trade construes a two-tier structure of justification under the article. First, it has to be examined whether the requirements of any of the eight headings are fulfilled. Of these, Art. XX (b) and (g) GATT appear pertinent. Second, the chapeau, which according to the WTO judiciary (US – Reformulated Gasoline, Appellate Body, p. 21; US – Shrimps, p. 2803) aims at preventing abuse of the exceptions of Art. XX, basic ally demands that the measures must not be applied in a discriminatory manner. Though BTA partly aim at changing behavior in other states, the consequences of global warming should establish a sufficient nexus to the territory.

2.4.1 Art. XX (b) GATT

Art. XX (b) GATT allows measures necessary to protect human, animal or plant life or health. This again implies a two-tier structure (US – Reformulated Gasoline, Panel Report, para 6.20). First, the policy of reducing CO2 emissions must be designed to protect human, animal or plant life or health. This can be easily ascertained for the import BTA, as the clause should not only allow measures to reduce immediately harmful emissions but also those of greenhouse gases which cause a global problem in the longer run (Zarrilli, 2003, p. 384), and as WTO members have the right to determine the level of protection they consider appropriate in a given situation (European Community – Asbestos, para 168). Problems arise, however, with respect to exports. BTA for these serve mainly the purpose of removing competitive disadvantages for domestic industry. As has been shown in the previous section, prices might be lower, implying more consumption. As a countervailing effect, existing demand can be satisfied by domestic producers who are more efficient than foreign ones. Hence, the overall effect on greenhouse gas emissions is ambiguous. Therefore, the rather difficult question arises as to what exactly constitutes the measure in question. Must the import and export measures be considered in isolation? Does the set of BTA form the measure? Or should one go even further and bundle all provisions on emissions trading into one measure? Seeing the passage of the directive without the adjustments and remembering the explanations of the Appellate Body in the US Gasoline report (pp. 13 f. on Art. XX (g) GATT), one would be inclined to reject the third proposal. But the second proposal is also subject to doubt. In theory, the two directions of BTA appear separable. The arguments advanced in favor of a symmetric treatment of exports and imports come into play here as well. Their weight should be sufficient so that the measure in question should indeed be BTA in both directions.

Second, the measure must be “necessary” in the sense that it must be the least trade-restrictive. An alternative measure, which is consistent, or less inconsistent, with GATT, must be used where that can be reasonably expected. This demands a process of weighing and balancing a series of factors, including the importance of the common interests protected by the measure, the contribution of the trade-restriction for the success of the protection of the interests and the impact on trade flows. The more vital or important the common interests or values pursued, the easier it is to establish that the measures in question are necessary to achieve those ends (Korea – Beef, paras. 162 ff.). With regard to the standards necessary to show that common interests are at risk and that the measure can help to disperse that risk, a member is not obliged to automatically follow what, at a given time, constitutes a majority scientific opinion. Hence, it can rely in good faith on a respected minority opinion (European Community – Asbestos, para 178). Accordingly, given the threat posed by global warming and considering the negligible negative impact on trade flows – the measures would still aim to level the playing field even if they came in a different guise than BAT adjustment – BTA for imports should meet the second test as well. Because of the symmetry argument, this extends to BTA in general. Hence, Art. XX (b) GATT is fulfilled.

2.4.2 Art. XX (g) GATT

Art. XX (g) GATT demands that the measure be related to the conservation of exhaustible natural resources if such measures are made effective in conjunction with restrictions on domestic production or consumption. In the Panel Report on the US – Reformulated Gasoline Case (para. 6.35), the panel construed the heading as having three requirements. First, the policy in respect of the measure for which the provision is invoked must be related to the conservation of a natural resource. This can easily be ascertained, as the aim of a reduction in greenhouse gas emissions at the same time contributes to the preservation of natural fossil fuel resources. Furthermore, one could probably argue that the atmospheric CO2 concentration constitutes a natural resource as well, considering the wide interpretation given to this term in paras. 127 ff. of the US – Shrimp Case and bearing in mind that, in the Panel report (para. 6.37) on the US – Reformulated Gasoline, Panel Report, it was held that clean air was a natural resource.

Second, the measure itself must be related to the conservation of natural resources. Initially, GATT and WTO panels held that “related to” should be interpreted as “primarily aimed at”. However, this rather narrow interpretation seems to have been replaced in the Shrimp/Turtles Case by a wider one, which only demands that the measure be “directly connected” to the conservation policy (van Calster, 1999, pp. 114 f.). As demonstrated above, BTA for imports would serve the environmental purpose of helping to ensure that the most efficient producers worldwide carry the day. Again taking symmetry as given, the direct connection would be fulfilled for BTA for imports and exports.

Third, there is the requirement that such measures must be made effective in conjunction with restrictions on domestic production or consumption. The clause demands even-handedness in the imposition of restrictions in the name of conservation (US – Reformulated Gasoline, Appellate Body, p. 19). The requirement that measures concerned must impose restrictions not only on imported, but also on domestic, products is clearly satisfied when one takes into account the fact that domestic products have been hit by a domestic tax at least as high as imported ones.

2.4.3 Chapeau of Art. XX GATT

As the second step, the chapeau requires that the measure in its application must neither constitute an (1) arbitrary or (2) unjustifiable discrimination between countries where the same conditions prevail, nor a (3) disguised restriction on international trade. All three criteria have to be met (US –Reformulated Gasoline, Appellate Body, p. 25). The standard must generally be lower than the one under Art. III GATT, as otherwise there could never be a justification for violations of that provision. When interpreting the provisions, the context of the norm and, in particular, the preamble to the WTO agreement as well as the preamble to the Decision on Trade and Environment all of which confirm the WTO´s undertaking to pursue the aim of sustainable development need to be respected. A balance must be struck between the right of a member to invoke an exception under Art. XX GATT and the duty of that same member to respect the treaty rights of the other members (US – Shrimps, pp. 2803 ff.). Factors taken into account have included the following. First, the fact that other countries would be forced to adopt virtually the same approach as the state taking the measure. Second, the failure to engage in serious negotiations with the other members before taking the measure (US – Reformulated Gasoline, Appellate Body, p. 28). Third, a differential treatment among various countries (US – Shrimps, p. 2810). The second factor can hardly be said to be the case for emissions trading schemes, in particular seeing the history of the negotiations for the Kyoto Protocol (different view held by Goh, 2004). The first and the third factor would have to be observed when implementing a BTA. In particular, it would appear necessary, if a scheme that was not in accordance with Art. III or I GATT were to be implemented, to take into account members' efforts at CO2 abatement and their respective obligations under the Kyoto Protocol, provided they are members. Hence, BTA for trade with Kyoto signatories would meet difficulties when these states chose a regulatory approach. This in turn threatens to introduce "Trojan horse regions" into the Kyoto system, who envisage trade with non-Kyoto regions without any BTA. These regions might then be able to export goods imported from non-Kyoto regions without BTA, if only after they have sufficiently modified them to fulfill the rules of origin. Anti-abuse provisions against such behaviour could result in significant uncertainty.

Hence, it can be said that if the first line of defense - i.e. that Art. III GATT is not violated, were to break down - the proposed scheme could still be maintained, as there is the possibility of a justification under Art. XX (b) and (g) GATT. However, the scheme would have to be carefully designed, in particular with respect to other Kyoto regions that pursue a different abatement regime. Therefore, it would seem wise to attempt to meet the standards of Art. I and III GATT.

2.5 Conclusion: BAT-BTA allowed under WTO-rules

It can therefore be stated with a reasonable degree of certainty that the introduction of the BTA scheme with reference technology levels set at BAT would indeed be admissible under WTO -rules. It seems worthwhile pursuing the path by examining some aspects of the practical implementation.

3 Implementation: BTA for Basic Materials and Electricity Only

In practice, BTA cannot be determined for every single product according to the quantity of CO_2 emissions producing this very product with BAT: for example, it would be very hard to determine what exactly constitutes a homogeneous product and what the BAT was for every single product.

Hence, only an indirect scheme – using a measure highly correlated with the quantity of CO2 emissions during production – seems possible. The starting point for such an indirect scheme should be the fact that a large fraction of CO2 emissions can be attributed to the production of basic materials. Therefore we must identify the quantity of different materials utilised in the production process. The BTA is then calculated by multiplying the quantities of different processed materials of which a product consists with the specific CO2 emissions associated with the production of the material. Electric energy input is treated separately, as explained in section 4.5. The resulting number will be a lower bound to total associated CO2 emissions, as additional emissions from the refinement process are ignored. Complexity can be further reduced by focusing on products where costs of CO2 in input materials exceed a threshold level relative to the product price.

To obtain the relevant quantities, producers of goods would have to specify which quantities of different basic materials are included in their product. The labeling would be easily verifiable, e.g. by critical competitors questioning the composition of the product. At the same time, the categories would be wide enough to ensure that no critical information is revealed to competitors. This would mirror a methodology well-established in the food industry: in many countries, food products have to state the content of the major components included in the product.

The following sections will explain in some detail how the emissions quantities for each unit of a processed good can be obtained, whether these quantities should be product- or production-specific, what criteria determine a BAT, and what size should be adopted for the processed materials classes. Then, the special treatment of the electricity input factor is discussed. Some remarks on grandfathering conclude the section.

3.1 Bottom-up approach preferable to top-down approach

Two basic approaches are established to determine the emissions associated with the production of a product. The top-down approach uses aggregate information on the energy consumption by different sectors (Carnegie Mellon (2003)). The economic input output model is then used to determine how many inputs from other sectors are directly or indirectly required to supply one unit of output of the assessed sector. In the bottom-up approach, production processes are individually examined. Weber, Jenseit and Fritsche (1999) compare the bottom-up and top-down analyses in the example of non-ferrous metals, and calculate approximately 50% higher emissions using the GEMIS bottom-up approach than the top-down approach based on the German input-output table. Discrepancies are attributed to different assumptions about electricity-generation mix, heat production and possible differences in the definitions of which products to attribute to the class. Our comparison indicates that a higher resolution of the production classes would be required to improve the accuracy of the top-down approach (Cambridge-MIT-Institute working paper 34). As increasing sectoral resolution is difficult, and also as any top-down decision could be challenged on a case-by-case basis with a bottom-up assessment, the latter seems to be more appropriate.

3.2 Border-tax at a product-specific rather than process-specific level

Typically, several production processes and facilities are available to produce identical final products. The economic and legal arguments presented in section 3 suggest disregarding the differences in the production *processes*. Rather, the BTA should be *product*-specific:

Within the BTA applying region, labelling requirements, under which producers would have to specify which processes were employed in the production of the product, would cause a large administrative burden. Moreover, such an approach would not have the required incentive properties. Products associated with high CO2 emission levels would be exported, because they receive higher border-tax adjustment. This is likely to result in additional transport volumes. Furthermore, process-specific adjustment levels would remove the incentive for companies to improve or shift the process towards more energy efficiency, because companies would receive less border-tax adjustment when exporting their product after adjusting the process. For imports into the area with border-tax adjustment, process-specific BTA levels also seem inappropriate. This would require monitoring of production-processes outside of the jurisdiction and it might be more difficult to defend in the context of WTO law, because it builds on a narrower definition of ‘like products’.

Electricity input constitutes a specific case. It can be produced at close to zero emissions from renewables or with very high CO_2 emissions from brown coal. For this reason, we suggest addressing electric energy input separately.

This still leaves us with the question of which fuel is used to produce process heat. In some chemical processes, specific fuels types are required, e.g. iron production is a coal-based process. In such processes, the calculation of CO_2 emissions is rather straightforward. More controversial could be processes which are not fuel-specific, e.g. provision of heat for drying chambers. Coal-fired heat production results in about twice the CO_2 emissions per unit of heat produced as gas-fired heat production. If both types of fuels are used in a certain process, then non-discrimination might require that the lower CO_2 emission fuel types serve as reference. However, this should not imply that fuels like biomass are suggested as reference for heat production. While biomass produces close to zero emissions over the life cycle, it is not (yet) replacing all fossil fuels. Therefore, it will continue to be priced at the fossil fuel price plus corresponding CO_2 allowance price. Hence, production based on biomass incurs the same cost increase from CO2 allowances.

3.3 *BAT* as reference technology level

Setting BAT as the reference technology level for BTA is legally warranted. Section 3.2 has already established that using average rather that best available technology would discriminate against producers outside the area which applies BTA. Foreign producers would incur higher costs than local producers if their production facilities are more CO_2 efficient than the average technology.

Furthermore, setting BAT as the reference level also makes economic sense. Domestic industry generally has an incentive to provide information to the institution determining the reference level that pushes the reference level towards a technology level with high emissions to ensure they get reimbursed for as much of CO_2 allowance cost as possible when exporting. Industries importing into the region with the high CO_2 price will provide information about more efficient technologies so as to reduce the level of import taxes. Making use of these diverging interests of local and foreign industry ensures that all information necessary to determine the level of border tax adjustment. This contrasts with usual industry interactions, during which all the industry provides information with the same bias to reduce the regulatory burden. The aim of the institution setting the border-tax adjustment level is therefore to create a transparent process. BAT – in contrast to the average technology mix – has the advantage that only one technological process needs to be evaluated.

We are left with the question of which technology should be labeled BAT. It should be a technology that is commercialised, perhaps by requiring a certain market share on the world markets of the products build with the BAT production process.

Basing the border-tax adjustment level on the BAT on the world market rather than the home market has a second advantage: it limits the distortions on technology choice in the home market. If the BAT applied in the home market were used as reference to set the border-tax adjustment level, incumbents would delay using the new technology in order to keep the border-tax adjustment they receive at a high level.

An issue we still have not addressed so far is how to treat new production processes that are more, rather than less, CO_2 intensive. The additional CO_2 intensity could be caused by higher environmental standards, which reduce non-CO_2 emissions, but require additional energy and cause additional CO_2 emissions. If the shifts are between different gases that contribute to climate change, the issue can and will be easily addressed by using CO_2 equivalent emissions rather than CO_2 emissions as the basis for the border-tax adjustment.[4] If the higher energy requirements are due to, for example, lower operation temperatures required to reduce NOx, then they will disadvantage producers that are exposed to the emission restrictions. BAT reference production process should therefore achieve the environmental standards required within the area in which the BTA is applied. Such a measure could induce the industry of the region that applies BTA to require higher environmental standards on a specific emission group to exclude a low CO_2 intensive production process. However, such behaviour is typically identified, if the purpose of excluding foreign products is apparent.

4 The CO2 equivalent emissions for the non-electric input in the cases presented in a study are between 7% (rubber) and 22% (aluminum) higher than CO2 emission. These differences imply that a consistent treatment is required and must be decided ex-ante. (Probas, Prognos/EWI 1999, Oeko-Institute, ETH 1995).

Product	Probas CO2/Kg
Al99 I	8,45
AlCuMg1	8,36
AlCuMgPb	8,45
AlCuSiMg	8,35
AlMg	8,54
AlMgSi	9,55
AlMn	8,4
AlZnCuMg	8,28
AlSiMgMn	8,43

Figure 2 CO2 Intensity of production of variations of Aluminum Aloids

Summarising, we would suggest using BAT to determine BTA levels, because it seems easiest to implement and compliance with WTO rules seems certain. Because of opposing interests of home and foreign industries, the institution setting the level border-tax adjustment should have access to all required information, so that a high level of accuracy of the decisions can be expected. The level must be set ex-ante, because otherwise trade will be severely damaged if traders face uncertainty about the BTA, given that commodity traders between stable economies typically operate on small margins.

3.4 Size of processed materials class

At the outset, we stated that each product would be delivered with a label which specifies the processed materials that entered into the product. The energy level would not be the energy level of the used production process but of the reference process using BAT. How many product categories, and therefore reference processes, do we need to define?

Plastics	Probas CO2/Kg
EPS	3,94
HDPE	2,51
HDPE-APME 99	1,88
LDPE	2,76
LDPE-APME 99	2,08
PP	3,67
PS	3,12
PS-APME 99	2,77
PS-ISI	2,75
PET	3,43
PVC	2,41
PVC-APME-99	2,12
PVC-ISI	2,56
PUR rigid expanded	5,38
PUR flexible foam	6,40
epoxy resin	6,33
waterproof layer HDPE	2,34
damp-proof layer HDPE	3,20
damp-proof layer LDPE - flame retarded	3,96
plastic generic	1,72

Figure 3 CO2 Intensity of production of different plastics

The following three reasons work in favor of large processed materials classes. First, the more processed materials classes are defined, the larger will be the administrative burden of defining the energy intensity of the reference processed materials and the smaller will be the incentive for industry to support the process with information. Second, the more processed materials classes are defined, the more difficult will it be for companies to classify a product they export correctly and for the customs authority to verify the classification. Given that customs authorities rely on the self-declaration of companies, which can only occasionally be verified, the companies only face a sufficient incentive to truthfully classify their product if misspecifications can be punished. However, if the specification is too difficult, then the company can dispute intentional misspecification, punishment is not possible and therefore enforcement fails. Third, the bigger a processed good class, the more companies will be competing in the class and the more likely it is that any one company will use a new, less CO_2 intensive, technology. Given that others are likely to use a new, less CO_2 intensive, technology, any individual firm has less incentive to postpone applying a new technology. Figure 2 illustrates that, for aluminum aloids, a subdivision can be avoided, as they exhibit similar energy intensities.

The disadvantage of large product classes, however, is that CO_2 intensity of the production can vary largely, as within the class of plastics (Figure 3). Within the class, we will face the difficulty of determining which product to use to determine the CO_2 (equivalent) emission per unit (weight) produced. The choice should be made in such a way that no-one has reason to suspect the intention of the adjustment is to discriminate against foreign producers. The chosen product should therefore be among the products with the lowest CO_2 (equivalent) emission in the class. This implies that the more divergent the CO_2 intensity of the production of different products within a class, the lower the proportion of CO_2 emission allowance costs that can be adjusted for at the border. This is the main driver for subdividing classes with non-homogeneous energy intensity of materials and increasing the number of product classes.

3.5 Electric Energy input

Certainly the most difficult energy input factor is electric energy. Electric energy is a freely tradable and homogeneous commodity. In integrated electricity systems, it is technically impossible to identify the origin of an electric energy delivery. We therefore propose a distinct treatment for electricity inputs. For electric energy input, we suggest directly compensating for the price change of electricity rather than for the emission allowances required to match the average fuel mix. All databases used for our analysis allow segregation between electric energy input and other input.

The electricity price change depends on the CO_2 intensity of the marginal generation technology. But CO_2 allowance prices can also alter the technology that sets the marginal price. Therefore a dispatch model, which is a standard and transparent tool, is required to compute the impact of CO_2 allowance prices on the electricity price. As European electricity systems are interconnected, the marginal electricity price is expected to be at or above the price of fossil generation and therefore likely to be increased all over the continent.

The observed price will always differ a little from such model approaches, mainly because of the generators with market power who bid their output at higher prices into the market. However, the size of the margin is not expected to vary systematically between cases with and without CO_2 emission allowances.[5]

Countries like Canada or Argentina, with large shares of hydro generation, could claim that their products are produced in an environmentally friendly manner, and should therefore not be exposed to the import tariff. However, even in those countries, marginal electric energy is produced or replaces fossil generation. Therefore any change in industry output will first result in a change of power production from fossil fuels. Nevertheless, if financial incentives are strong enough, industrial plants could build a dedicated power line to a non-fossil generation plant to claim that they only use and are the only user of this energy. It could therefore be difficult to defend any fuel mix for electricity with positive contributions of fossil fuels when determining the tariff of border tax adjustment for products. In contrast, by interpreting electricity generation as an aggregate input into the industrial production process, the CO_2 emission allowances can be interpreted as a tax on electric energy. This tax will be compensated for, irrespective of the underlying evolution in the electricity industry.

4 Conclusion

This paper has demonstrated that BTA for the emissions trading scheme is an economically viable approach to address leakage effects. It is in conformity with WTO law where the adjustment level does not exceed the upper bound of the amount payable for production in the area covered by emission trading using best available technology. To make the scheme implementable, we propose a processed-materials approach where these are in turn evaluated at the level of best available technology. As Demailly and Quirion (2005) have shown for the cement industry, such evaluation at BAT does not necessarily imply additional leakage for primary materials. In contrast, adjustment for

5 Analysis of California experience has shown that extreme scarcity of NOx emission certificates created high prices and possibly reduced output from controlled generation. However, a larger area affected by CO2 emission certificates, plus banking options, should reduce the risk of large price spikes on CO2 emission certificates, which could affect the impacts on the exercise of market power.

electricity as a homogeneous commodity should follow the price increase induced by Carbon Emission Certificates relative to a situation without such emission allowances.

5 Appendix

In the following calculations, we assume that demand in two regions A, B is described by differentiable demand functions $D_A(P), D_B(P)$. Several facilities are available to produce the same product. The facilities differ in the amount of energy $\tau + \alpha$ that is required for the production of one unit of output, with τ fixed and $\alpha \geq 0$ technology specific. The quantity of installed production capacity $(\alpha \leq \alpha')$ with energy efficiency equal to or higher than α' in each region is characterised by the supply functions $Q_A(\alpha'), Q_B(\alpha')$. To simplify the subsequent calculations, we assume Q is differentiable. This can be either interpreted as an approximation in the limit of many firms or as any one production plant being represented by an interval of different αs , e.g. increasing output changes energy input. The marginal costs C of technology α are composed of the basic energy costs C_0 and the additional costs for emission allowances or carbon tax C_C :[6]

$$C(\alpha) = (\tau + \alpha)(C_0 + C_C) \qquad (1)$$

As a reference case, we first assume global implementation of CO_2 emission allowances. Global demand equals global supply, and the global marginal technology α_G is defined in such a way that global price P_G equals marginal costs (*1):*

$$Q_A(\alpha_G) + Q_B(\alpha_G) = D_A((\tau + \alpha_G)(C_0 + C_C)) + D_B((\tau + \alpha_G)(C_0 + C_C)) \qquad (2)$$

To determine the change of the marginal technology with changes of emission costs we differentiate *(2)* with respect to C_C with $Q' > 0, D' < 0$:

$$\frac{\partial \alpha_G}{\partial C_c} = \frac{\tau + \alpha_G}{\frac{Q'_A + Q'_B}{D'_A + D'_B} - (C_O + C_C)} < 0\,. \qquad (3)$$

With increasing costs of emission allowances, a smaller set of facilities is applied, and therefore the global price increases (using *(3)*):

$$\frac{\partial P_G}{\partial C_c} = \frac{\partial C(\alpha)}{\partial C_c} = \frac{Q'_A + Q'_B}{D'_A + D'_B} \frac{\tau + \alpha_G}{\frac{Q'_A + Q'_B}{D'_A + D'_B} - (C_O + C_C)} > 0\,. \qquad (4)$$

In a second step, we assume that emission allowances are only implemented in region B while costless global arbitrage in the product market continues. Therefore, marginal facilities α_P^A and α_P^B differ in both regions to ensure the competitive price stays uniform:

6 Note that we assume that all energy input will correspond to the same amount of carbon emissions. First, this requires a separate treatment of electric energy input (as suggested in the paper) to take into account the different generation-mix of coal, gas, nuclear and renewable plants, which corresponds to different CO2 emissions. Secondly, some production processes can be operated with different energy inputs (e.g. steel production with coal or electricity), and therefore additional (discrete) shifting would have to be represented, but should not affect the final outcome significantly.

$$P = (\tau + \alpha_P^B)(C_0 + C_C) = (\tau + \alpha_P^A)C_0 . \qquad (5)$$

Expressing α_P^A as function of α_P^B the equality of supply and demand implies:

$$Q_A(\alpha_P^B \frac{C_0 + C_C}{C_0} + \tau \frac{C_C}{C_0}) + Q_B(\alpha_P^B) = D_A((\tau + \alpha_P^B)(C_0 + C_C)) + D_B((\tau + \alpha_P^B)(C_0 + C_C)) \qquad (6)$$

In this case the change of α_P^B with C_C is given by:

$$\frac{\partial \alpha_P^B}{\partial C_c} = \frac{(\tau + \alpha_P^B)\left(1 - \frac{Q'_A}{D'_A + D'_B}\frac{1}{C_0}\right)}{\frac{Q'_A + Q'_B}{D'_A + D'_B} - (C_0 + C_c) + \frac{Q'_A}{D'_A + D'_B}\frac{C_C}{C_0}} . \qquad (7)$$

Comparing the change of the marginal technology *(3)* with *(7)* shows that $0 > \frac{\partial \alpha_G}{\partial C_C} > \frac{\partial \alpha_P^B}{\partial C_C}$ if $Q'_A + Q'_B > C_0(D'_A + D'_B)$ .The condition is always satisfied as $Q' < 0$ and $D' > 0$; therefore, we can conclude:

Proposition 1: *With partial implementation, production in region B is weakly more reduced than with full implementation of CO_2 emission allowances.*

To assess the impact of partial implementation on output in region A, we differentiate using *(5)* to express α_P^A as function of α_P^B and differentiate with respect to C_C and substitute *(7):*

$$\frac{\partial \alpha_P^A}{\partial C_c} = \frac{(\tau + \alpha_P^B)}{C_0} \frac{\frac{Q'_E}{D'_A + D'_B}}{\frac{Q'_A + Q'_B}{D'_A + D'_B} - (C_0 + C_c) + \frac{Q'_A}{D'_A + D'_B}\frac{C_C}{C_0}} > 0 .$$

The result can be summarised:

Proposition 2: *With partial implementation, output in region A increases relative to no implementation.*

Finally we want to assess the impact on prices. Differentiating *(5)* with respect to C_C , gives:

$$\frac{\partial P_P}{\partial C_c} = \frac{\partial \alpha_P^A}{\partial C_c} C_0 = \frac{(\tau + \alpha_P^B)\frac{Q'_E}{D'_A + D'_B}}{\frac{Q'_A + Q'_B}{D'_A + D'_B} - (C_O + C_C)\frac{Q'_A}{D'_A + D'_B}\frac{C_C}{C_0}} > 0 . \qquad (8)$$

Comparing with *(4)* shows $\frac{\partial P_G}{\partial C_C} > \frac{\partial P_P}{\partial C_C}$

Proposition 3: *With partial implementation, the global product price increases, but by less than with full implementation.*

Now we assume border taxes t are set at the level of the BAT: $t = \tau C_C$. Importers into region B have to pay t per unit of goods, and exporters receive a reimbursement for the higher energy costs of t. Therefore the product price levels will be $P_T^B = P_T^A + t$. This defines the relationship between the equilibrium facilities α_T^B and α_T^A in both regions:

$$\alpha_T^B \left(1 + \tfrac{C_C}{C_0}\right) = \alpha_T^A . \qquad (9)$$

Using again the market-clearing condition that demand equals supply:

$$Q_A(\alpha_T^B \left(1 + \tfrac{C_C}{C_0}\right) - \tau) + Q_B(\alpha_T^B) = D_A(\alpha_T^B (C_0 + C_C)) + D_B((\tau + \alpha_T^B)(C_0 + C_C)) ,$$

and differentiating with respect to C_C gives:

$$\frac{\partial \alpha_T^B}{\partial C_c} = \frac{(\tau + \alpha_T^B)\left(1 - \frac{Q_A'}{D_A' + D_B'} \frac{1}{C_0}\right) - \tau \left(\frac{D_A' - \frac{Q_A'}{C_0}}{D_A' + D_B'} \right)}{\frac{Q_A' + Q_B'}{D_A' + D_B'} - (C_O + C_C) + \frac{Q_A'}{D_A' + D_B'} \frac{C_C}{C_0}} . \qquad (10)$$

Comparing *(10)* with *(3)* and *(7)*, we obtain $\frac{\partial \alpha_P^B}{\partial C_C} < \frac{\partial \alpha_T^B}{\partial C_C} < 0$. This implies that producers in region B are better off with BTA. The effect on producers in region A can be determined by differentiating *(9)* with respect to C_C and substituting from *(10)*:

$$\frac{\partial \alpha_T^A}{\partial C_C} = \frac{\tau \frac{D_B'}{D_A' + D_B'} \frac{C_0 + C_C}{C_0} + \frac{Q_B'}{D_A' + D_B'} \alpha_T^B \frac{1}{C_0}}{\frac{Q_A' + Q_B'}{D_A' + D_B'} - (C_0 + C_C) + \frac{Q_A'}{D_A' + D_B'} \frac{C_C}{C_0}} . \qquad (11)$$

If $\frac{\partial \alpha_T^A}{\partial C_C} > 0$, then implementation of CO_2 emission allowances with BTA in region B increases production in region A.

Proposition 4: *Producers in region A will benefit from the introduction of CO_2 emission allowances with BTA in region B if:*

$$-\frac{\partial Q_B}{\partial P_T^B} > \frac{\partial D_B}{\partial P_T^B} \frac{\alpha_G}{\tau} \qquad (12)$$

This is the case if the supply is more responsive to price changes than demand or if the dispersion of energy-efficiency of different facilities α_G is large, relative to the basic energy demand τ.

If facilities are not uniformly distributed and Q_B' is not constant or demand is not linear and D_B' not constant, then (12) is a sufficient, but not a necessary, condition. The necessary condition is $t < \int_0^{C_C} \frac{\partial P_T^B}{\partial C_C} dC_C$. If the necessary condition is not satisfied, then partial implementation of CO_2 emission allowances with border-tax adjustment at the level of BAT results in a reduction of production in region A.

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