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Trade and Climate Change: The Challenges Ahead*

Nicole A. Mathys
Jaime de Melo

Nicole A. Mathys is Responsible for research program "Energy-Economy-Society" at the Swiss Federal Office of Energy, Berne. She is also Researcher and Lecturer at the University of Neuchâtel.

Jaime de Melo was Professor at the University of Geneva from 1993 to 2012. His research focuses on trade policies, on trade and the environment, on the links between regionalism and multilateralism. He is Senior Fellow at Ferdi since 2011.

Abstract

The outcome of the 15th conference of the Parties to the UNFCC showed a shift from a top-down approach with a collective target favoring environmental objectives to a bottom-up accord favoring political feasibility, with no meaningful binding agreement in sight, as the global climate regime and the global trade policy regime represented by the WTO appear to be on a collision course. Following a review of the alternative architectures for the next Climate Change Agreement, the paper outlines four areas in which trade will play a role: as a purveyor of technological transfer; as a mechanism to separate where abatement takes place from who bears the cost of abatement; as a participation mechanism; and as a way to address the pressures for border adjustments. Political-economy considerations are invoked to predict that a target system with a carbon credit system will be preferable to a carbon tax or to a portfolio system of treaties. …/…

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Jaime de Melo

University of Geneva, CERDI and CEPR

Jaime.deMelo@unige.ch

and

Nicole A. Mathys

Swiss Federal Office of Energy and University of Neuchâtel

Nicole.Mathys@gmail.com

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ABSTRACT

The outcome of the 15th conference of the Parties to the UNFCC showed a shift from a top-down approach with a collective target favoring environmental objectives to a bottom-up accord favoring political feasibility, with no meaningful binding agreement in sight, as the global climate regime and the global trade policy regime represented by the WTO appear to be on a collision course. Following a review of the alternative architectures for the next Climate Change Agreement, the paper outlines four areas in which trade will play a role: as a purveyor of technological transfer; as a mechanism to separate where abatement takes place from who bears the cost of abatement; as a participation mechanism; and as a way to address the pressures for border adjustments. Political-economy considerations are invoked to predict that a target system with a carbon credit system will be preferable to a carbon tax or to a portfolio system of treaties. A review of evidence on the extent of pollution haven effects suggests that these should be small under climate mitigation policies, especially if efforts are undertaken to raise the price of energy. A discussion of border measures to complement mitigation policies suggests that they are unlikely to be found compatible with the environmental exceptions allowed under article XX of the GATT. The review concludes that an umbrella agreement with leeway where much initial mitigation would first take place unilaterally as under the early days of the GATT might be the most promising way ahead while preserving an open World Trading System and environmental integrity.

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1. Introduction

As the financial crisis is getting behind us, sustained growth is expected to continue largely because the globalization of the last decades has unleashed technical progress that spreads increasingly rapidly across countries. It is also expected to continue because it is taken for granted that today's open World Trading System will continue to function adequately. At the same time, the continuing difficulties at the Climate (Copenhagen) and trade (Doha) negotiations echo the concerns that the equity challenge of growth recovery are not being met as the stalemate in these negotiations have the same losers: the least developed (LDCs) and other vulnerable countries. Weak institutional infrastructures making it difficult for LDCs to carry out the policies needed for a sustained recovery, and to design policies that will include mitigation and adaption measures to deal with climate change. And in the case of the climate negotiations, in spite of the reassuring communiqués at the UN Climate Change conference in Poznan in December 2008 that the commitment to negotiating a Post-Kyoto conference would not be delayed because of the financial crisis, little was achieved at the Copenhagen conference a year later.

Several observers view the shift at the December 2009 meeting in Copenhagen from a top-down approach with a collective target under the current Kyoto protocol (KP1) to a bottom-up accord as a shift from an approach favoring environmental objectives to one favoring political feasibility, an approach under which there is no agreed standard for saying whether a country is or is not doing its fair share to limit global warming. With the UNFCCC working by consensus, a meaningful binding agreement with a dispute settlement mechanism akin to the one in the WTO does not appear in sight at the next meetings, including at the conference in South Africa in 2011. Some say that the global climate regime and the global trade policy regime represented by the WTO are on a collision course. Businesses fear about the mitigation policies affecting their competitiveness, and environmentalists fear that international trade will undercut the policies to reduce Greenhouse Gases (GHGs) emissions. Both groups are appealing to the WTO for rescue.[1]

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[1] Waters are further muddled by factual errors and some disagreement in the scientific community and its impact on public opinion as well as differences about what needs to be done as reflected in the very different prognoses in Nordhaus (2008), Stern (2009) and McKibbin (2010). Frankel (2008), Hufbauer and Kim (2010) and others see a train wreck between Climate change objectives and trade. One source of relative consensus is that damages will mostly fall on poor countries with little capacity

For a long time, trade and the environment have been odd bedfellows as environmentalists have claimed that the interests of the trade community as represented at the WTO would trump environmentalists concerns. First, globalization-induced increase in trade can magnify cross-border pollution. Second, improvements in technology make it increasingly easier to intensify the exploitation of natural resources, potentially exacerbating the depletion of natural capital. Recognizing the importance of these issues, the launch of the Doha Round explicitly recognized that environmental concerns would be fully taken into account during the round to address the fears that the gains from growth and globalization could be undermined by their environmental side-effects.

As a consequence of globalization, decisions at the national level have a growing impact on other countries. This changing landscape motivated the creation of the Global Task Force on Public Goods in 2003 and many policy publications that have addressed the need to expand the provision of the global commons: biodiversity and ecosystems, water resources, fisheries and now, mitigating climate change, the 'ultimate' Global Public Good. But the sheer magnitude of the climate problem justifies the fears that trade and climate change objectives may be heading for a collision with businesses.

This paper takes stock of the challenges ahead starting from the observation that the trade negotiations and the environment negotiations both face the same problem: providing a 'public good' whose supply requires widespread participation and compliance. Drawing on this analogy, we point out that the environmental negotiations can learn from the past evolution of the World Trading System, first under the GATT, then under the WTO. We recognize though that there is a fundamental difference with respect to the compliance that is necessary to bring about collective action in the case of climate change policies: as reminded by Barrett (2010), trade is bilateral, so that trade agreements can be more easily enforced by a strategy of reciprocity. On the other hand, climate change mitigation is a global public good where reciprocity is a weak enforcement tool. It is rarely in the interest to enforce the sanction on non-participants as those who impose sanctions are hurt in

at adaptation. Recent estimates put up to 80% of the damages from climate change would be in low latitude countries (Mendelsohn et al. 2006).

the process. It is not surprising, then, that the Kyoto protocol did not include trade sanctions as an enforcement mechanism.

Four aspects that complicate the design of appropriate trade policies to deal with mitigation and its consequences are addressed. First, any serious attempt at mitigation will require a higher price, perhaps around 100$ per metric ton of CO_2 equivalent. Due to the excessive distribution of emission permits, currently the price in the over-the-counter market in the ETS is around 20$ per metric ton. This will result in huge rents that contestability will lead to much resource waste that should be addressed in the architecture of the next climate agreements. Second, all forms of energy generation requires irreversible investments in capital equipment with long life in all forms. Very forward-looking decisions under uncertainty require a relatively predictable price of carbon, the predictability being enhanced by a multilateral framework outlining the contours of the path ahead, a requirement that cannot be achieved by unilateral action (the life of investment project are above 50 years for electricity generators and up to 60 to 100 years for residential buildings). Third, measuring the emission of GHGs in manufacturing and in agriculture is difficult, complicating the measurement of leakage. Furthermore, the carbon-content of energy is not visible in a product, complicating the application of border measures to counter any leakage towards non-signatories. Fourth, as mentioned above, since the damages from GHGs are truly global, it is extremely difficult to achieve the necessary collective action (benefits are shared by all while costs are only borne by participants), suggesting that starting with unilateral actions to build confidence and reduce the gaps might be necessary.

Section 2 delineates desirable features for a multilateral agreement and the role of trade and trade policy in an evolving World Trading System where climate change occupies a progressively larger role. Section 3 discusses political-economy constraints recognizing that the least efficient architecture will most likely be adopted where concerns about competitiveness and leakage are likely to cause trade conflicts. Section 4 then examines the evidence on leakage effects from a carbon tax by examining first the evidence of ex-post leakage in the case of SO_2, a pollutant that is prevalent in the same sectors as CO_2. We then report on the ex-ante estimates for CO_2 questioning the likely accuracy of these estimates. We also discuss the consequences for developing countries of alternative border adjustment measures. Section 5 tackles the uncertain legality of border adjustment measures at the WTO and the recent stalled initiatives to reduce protection on environmental goods. Section 6 closes with some thoughts about some lessons that the multilateral trading system could offer to the Climate Change negotiators.

2. The Contours of the Next Multilateral Climate Agreement

The challenge ahead is clear from figure 1 which shows the evolution of CO2 emissions (outside of agriculture) over the past 40 years for a very large sample of countries. Even though it does not include all sources and sinks it captures the emissions that are likely to be amenable to the trade policy levers that are the concern of this paper since it includes all emissions from fossil fuel consumption, cement manufacturing and gas flaring, ignoring fuels supplied to ships and crafts. Note that for the world as a whole, emissions growth has not slowed down since concerns about climate change surfaced around 1990. Since GHGs stay in the atmosphere for over a century, the stock is increasing. Much of this growth comes from the catch-up of the G3 (Brazil, China, India) shown in the middle panel. As with almost everything else on climate where the only 'certainty is uncertainty', orders of magnitude of the marginal damage are largely unknown, but there is now broad consensus that damage from emissions will increase at least until stabilization in the stock is achieved. Figure 1 also shows that per capita emissions (PCE) have stabilized for the three high-income heavy per-capita emitters (Australia, Canada, US or 'E3') in spite of GDP growth and population growth, though at levels about four times higher than the 'safe' levels (see figure 2). It is also evident from the middle panel that differences in per capita emissions are huge across country groupings and that the E3 have a long way to reduce their PCE to the OECD-26 group. Finally, note that CO2 emissions fell sharply during the two oil spikes in the price of oil in the 1970s. This indicates that a tax on the price of fossil fuel would lead to a fall in emissions.

Figure 1 here: Total and per capita carbon emissions 1960-2002

Three arguments opt in favor of acting now. First, because the uncertainty is not marginal, and the possibility of a tipping point lowers the discount rate calling for early action (there is also the issue of intergenerational equity which has been debated in connection with the Stern report). Second, the hardest hit will be the poor calling for action now to reduce the adverse effects they will be subject to. Third, the investments in green renewable energy called for are long-term and investment decisions are inherently dynamic. The longer action is delayed, the more investment will take place in emission-intensive activities because they will remain relatively more profitable than clean energies. However, the slow pace at which collective action is building up, indicates that acting rapidly will not happen.[2]

Because of the magnitude of the problem, mitigating climate change will require taking actions on several fronts:

(i) increasing R&D spending, both public and private to develop green energies;
(ii) combat deforestation since it is an important source of GHG emissions (see figure 3);
(iii) providing aid to support adaptation in the often-hostile environments in LDCs;
(iv) establishing an effective emission trading regime when countries choose to reduce emissions by issuing permits, a choice that could be adopted along with a tax and technical regulations in certain sectors.[3]

2.1 Addressing Equity Concerns

The UNFCC framework calls for "common but differentiated responsibilities" in addressing climate change as well as long term flexibility in implementation. In particular, any successful climate change regime will have to address burden sharing to take into account that since around 1990 (if we limit our self to the period for

[2] Against acting rapidly is the concern that the marginal cost function for mitigation may be very steep. For some, because marginal damages rise as GHGs accumulate, the optimal policy is dynamic growing stricter over time (see e.g. Nordhaus (2008)).
[3] All three approaches require measurement of carbon emitted. Trading schemes beyond hydrocarbon products will be severely limited by the costs and difficulty of measuring emissions; hence the three levers to reducing emissions (Schmalensee, 1998). Geo-engineering is also likely to be on the menu, but for most, it is considered a last-resort option with carbon capture and storage probably a more promising avenue (see Barrett (2008))

which climate warming became a widespread public concern), high-income countries have been responsible for a larger share of the current stock of concentrations. Taking into account intra and inter-generational equity will also require that countries converge on some per capita measure. The two broad alternatives are “per capita comparability” and “carbon price equivalency”. For political-economy reasons discussed in section 3, it is unlikely that a ‘top-down’ approach with an agreement calling upon countries to converge on a carbon price subject to sanctions for deviation will be agreed upon rapidly in spite of its superiority on economic grounds because countries are reluctant to acquiesce to subsidiarity on tax matters (see box 2 on difficulties in the EU in converging on a tax rate on energy).

Any broadly supported agreement will then have to rely on some convergence towards equal entitlements on a per capita basis, some arguing that it should be in terms of access to energy needs rather than emissions.[4] Taking convergence in per capita emissions (PCE) as an equitable target, Spence (2009) computes such emissions paths over a 50-year period. As shown in figure 2, PCEs would have to decline by 4% per year in the E3 (Australia, US and Canada) and by 2.6% per year in the other high-income countries (mostly the OECD 26 in figure 1). This means that all but the “other developing” slow-growing countries in figure 2 will have to accept being part of an agreement that will call on caps in the near future. Figure 2 shows the emission path for four groups of countries, two high-income groups and two developing country groups that correspond loosely with those identified in figure 1.[5] The paths for the fast-growing developing countries include the G3 in figure 1. While

[4] The approach using the “80-20” (the burden split between industrialized and developing countries) formula is often advocated and corresponds to an equal division between the estimated 9 billion people in 2050 implying that every citizen has an equal right to pollute the global sink, i.e. an equal right to emissions. In the press, in the US, the focus is on China’s total emissions exceeding those of the US while in China and India, the focus is on per capita emissions. Birdsall and Subramanian (2009) propose an alternative metric: we should concentrate on the right to have access to energy (rather than the right to pollute) and that history should be the guide. This means that people should have access to the same energy at comparable incomes per capita. However, developing countries should meet their energy needs with the technology frontier (not the technology of the developed countries earlier on at the same stage of development). Considering cumulative emissions, the obtained Gini coefficient comparing countries, is of the same magnitude as Gini coefficients based on income inequality in countries with the highest inequalities (richest 23% accounted for 62% of emissions in 2004). Alternative criteria (and starting points) to allocate responsibility are discussed in Muller et al. (2007) and Karp and Zhao (2009b).

[5] Note that carbon emissions are reported in figure 1 and CO_2 emissions in figure 2. The conversion factor is 3.67.

these countries PCEs are allowed to increases initially to dampen effects from mitigation on growth, it is clear that they will also have to reduce emissions soon.

Figure 2 here: CO2 per capita emissions on path to safe target

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These trajectories suggest the building blocs in the architecture for the next climate agreement. First, there should be broad participation in any future agreement that would recognize that fast growing developing countries should 'graduate' soon from their current status under KP1. This 'graduation' means being part of a cap on emissions. Second, because the uncertainty is great—a factor of 3 according to Schelling (2007)—as every time we learn something new, we also learn that there is something else we did not know, there is a need for regular negotiations along the path (the specificities of each successive agreement taking place every 5 years). The current Kyoto Protocol (KP1) that covers the period 2008-2012 recognized this issue, as targets are up for renegotiation after a five-year period.

2.2 Trade and Trade Policy to Address the Kyoto Failure

It is largely agreed that the current Kyoto Protocol (KP1) will have been largely ineffective in terms of reducing emissions because of lack of enforcement and low participation. This calls for a new architecture and it is interesting that early on, several commentators observed that insufficient attention had been paid to its architecture which was "deep and shallow" rather than "broad, then deep" (see e.g. Schmalensee (1998)). The lack of compliance mechanisms is particularly noteworthy (see box 1 on the KP1) and a comparison with the hugely successful Montreal Protocol (MP) that addresses ozone depletion, another global public good, is instructive even if ozone depletion and climate change are very different problems (the benefit-cost calculus of preventing ozone depletion is far more favorable than for climate change so that depletion could be halted at low costs).

Barrett (2010) argues that trade policy played a significant compliance role in the MP. First, all countries complied in the MP via strong incentives for compliance (trade sanctions) and participation (financial payments from rich to poor nations).

Also the MP minimized trade leakage by putting a cap on consumption (which is derived as production – exports + imports) whereas KP1 only puts a cap on production. Finally the MP caps are permanent, thereby stimulating innovation. Interestingly, the MP is estimated to have been indirectly far more effective at mitigating HFCs (a by-product of HCFCs , an ozone-depleting substance that is a GHG not covered by KP). Had HFCs been addressed in a separate (i.e. a sectoral) agreement, they could have been cut dramatically, and perhaps phased out. The MP was also strengthened over time with 7 amendments (see Barrett 2010, appendix B), i.e. its architecture was "broad, then deep" rather than "deep and shallow" as under the KP1.

BOX 1: Kyoto Protocol: Participation and Compliance

The Kyoto Protocol (KP) is the follow-up to an interim step agreed at the 1992 Framework Convention on Climate Change (FCCC) which established the objective of leveling GHG emissions among countries "on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities". The KP, negotiated in December 1997, would enter into force with a minimum of 55 countries accounting for at least 55% of global emissions of Annex I countries emissions. (Countries agreeing to legally binding commitments were called Annex B countries, almost the same list as Annex I countries under the FCCC). The US withdrew in 2001 both because of the stiff target on emissions (7% below 1990) and the exemption of major developing countries from emission constraints when a 95-0 vote in the Senate killed it, the vote reflecting the bipartisan concern of 'leakage'. Shortly thereafter, Australia also dropped out. KP1 finally came into force in 2005 when flexibility was added (see below), rules for 'carbon sinks' were watered-down, and Russia was brought on-board as an Annex B signatory with a non-binding ceiling. Annex B countries agreed to cut GHG emissions relative to 1990 by an average of 8 percent below 1990 levels over the interim period 2008-2012 (KP1). The targets apply to six GHGs: carbon dioxide (CO2), methane, nitrous acid, nitrous oxide, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6). Together, Annex B countries account for ¼ of total emissions so, participation is low justifying concerns about leakage.

Three flexibility mechanisms were introduced to lower the costs of meeting commitments: (i) international emissions trading (allows Annex B countries to trade a portion of their assigned amounts); (ii) joint implementation (JI) allows countries to cooperate on projects and transfer emissions on the basis of those projects, and the Clean Development Mechanism (CDM) allows Annex B countries to finance projects in non-Annex B countries in exchange for negotiated credits or CERs that count towards meeting their own emission commitments. The KP also focuses on net emissions allowing carbon sequestration to be substituted for abatement. It is likely that the emissions over the 5-year period covering KP1 will be about those that were predicted without the Treaty (Mendelsohn (2009)).

Unlike the very successful Montreal Protocol (MP) which included trade restrictions between parties and non-parties, even though commitments are legally binding, under KP1 article 18 prohibits the use of a compliance mechanism that would entail "binding consequences" unless adopted by amendment to the treaty. As under the GATT, a sanction against a party has to be approved by the party it is aimed at. As to the suspension of emissions trading privileges, countries would probably be unwilling to enforce them. The KP1 failed to promote compliance (many countries used accounting that violates the treaty) and participation (developing countries do not undertake commitments).

The Copenhagen Accord of December 2009 sets as objective for KP2 to limit temperature rise to 2° above pre-industrial levels. According to Stern and Taylor (2010), if the 75 countries that account for 80% of CO2 emissions who have submitted targets to the Accord, deliver on their "high intention" reductions, global emissions would fall from the 55 billion metric tons (bmt) under BAU to 48 bmt.

This would represent a half-way reduction towards the estimated safe 44 bmt needed to keep temperatures from rising above 2° with a 50% probability. Also a high-level advisory group has been established to suggest ways to transfer 100$ billion per year from public and private sources to developing countries by 2020.

If participation, and compliance were the missing elements in the KP1 and trade was integral in achieving both compliance and participation under the MP, what potential role is there for trade policy under the KP2 and its successors? Trade could come into play through four channels. First, an open trading system with high trade volumes (and IPRs that recognize that technology transfers will have to be encouraged at the same time that incentives for R&D are maintained) is essential. This is because much technology development and transfer takes place through trade.

Second, it will be necessary to separate where abatement takes place from who bears the costs of abatement. Marginal costs of abatement differ widely with many 'no-regrets' energy-saving opportunities in developing countries. Under those circumstances, a global carbon credit trading system (CCTS) building on an improved Clean Development Mechanism (CDM) introduced under the KP1 will be necessary. Implementing the CDM involves not only trade in credits but also trade via technology transfer.

Third, trade sanctions could enter as a participation mechanism (see the comparison of the Montreal and Kyoto Protocols in box 1) although how the sanctions role would be rendered effective is difficult to assess but likely to be more promising if the new architecture leans towards a system of treaties (see below). Countries participate in an international treaty mostly to influence the participation of others and of non-signatories (rather than to tie their hands). Members of an international agreement can establish trade sanctions for non-participants who do not comply, as in the case of the Montreal Protocol although, to be successful, it requires a high degree of participation, thereby obviating the use of trade sanctions. This has the advantage that new principles could be drawn up for a climate change treaty rather than relying on the current complicated rules governing the use of border adjustment measures to address competitiveness effects (see section 5). For example, only a handful of high emitters of CO_2 would be covered under the new set of rules. Building such an agreement might be easiest with few participants, but this would come at a cost since a substantial amount of trade might then take place among non-participants making it costly (and hence not credible) for participants to apply the agreed-upon sanctions. One should however be cautious in transposing trade measures that worked under the MP on greenhouse gas agreements. The dimension of the problem is much larger in the latter case and hence any trade sanctions have larger effects and might potentially be much more destructive.

Fourth, is the issue of 'leakage' and the pressure for border measures discussed in section 4. While non-CO_2 evidence suggests that leakage may not be as important as one might be led to believe, the pressure for countervailing action against countries (like the US) that in effect subsidize their industries by not correcting the externality due to CO_2 emissions will be great and it has already surfaced under the mild cuts of the KP1. It is hard to imagine that this pressure will not be concretized in the successors to the KP1 and trade wars are a real possibility as the parties involved are major players in international trade (EU, US, China). Dealing with the pressure for border adjustments will be an integral part of the current negotiations on climate change. As discussed in section 5, the WTO-legality of border measures is uncertain and current rules appear inadequate to deal with the leakage issues raised by CO_2 emissions.

3. Political Economy Considerations

Any serious attempt at dealing with climate change will have to establish a carbon price, anywhere up to 100$ per ton, generating rents of a magnitude never seen before in the World Trading System. Dealing with rent transfers nationally and internationally will dominate efficiency considerations in the final decisions since high GHG emitters are powerful groups in the energy, construction, transportation and manufacturing sectors. Three approaches dealing with implementation are briefly described in descending order of desirability according to economic criteria: (i) carbon taxes; (ii) a system of Treaties; (iii) a target system with a carbon credit trading system. The third approach, already used in other circumstances on a smaller scale, is likely to prevail. It is the approach that will get most support as it will allow for the most capture leeway for rent-sharing among the powerful parties involved.

3.1 What Architecture?

A Carbon Tax By far, this is the preferable option on economic grounds (see e.g. Cooper (2008) for a discussion of the appeals of this approach). First, millions, if not billions of agents take energy-related decisions so the surest way to reach them all is through the transparency of the price system. This is the strongest, and very, compelling reason in favor of a tax. Second, it corrects the problem at its source (although under enough assumptions, some not likely to be met, it is equivalent to a cap-and-trade system). A carbon tax also goes a long way towards re-establishing optimality. Third, it is much more easily verifiable than most of the other approaches which aim to put a ceiling on all six GHG gases whose emissions are difficult to verify. Indeed, a major difficulty with the favored cap-and-trade system is that substantial up-front costs will have to be made to make it verifiable whereas a tax on gasoline and electricity is easy to verify. Fourth, if the tax is the same, or it is agreed that the different tax rates will converge across countries, the leakage problem would be largely resolved. Fifth, the thorny issue of the mechanisms for burden sharing is lessened since most, if not each, country will get some revenue from the tax. Sixth, even though there is all-round uncertainty, it is likely that the marginal benefits from reductions in the flow of emissions are quite elastic, if only because the damage depends on the stock of emissions. On the other hand, uncertainties about the marginal costs of abatement are large. Under that configuration, as first shown by Weitzman (1974) and confirmed in later studies (see Karp and Zhao (2009) for a summary), the welfare benefits of using the price mechanism are likely to be greater than those associated with using a quantity target.

A Portfolio System of Treaties This approach, advocated by Barrett (2008) has many appeals. First, it has worked in the case of the Montreal Protocol (MP), which is essentially a sector approach to the reduction of a global public bad, ozone-depletion. A sector approach would be appropriate for reducing emissions in aviation, maritime and road transport (left out of KP1 for good reason because they are international trading systems and a common standard must be adopted). Indeed, a restriction on emissions at the country level would lead to extreme leakage---ships would re-register in a non-party to the treaty. As shown by the successful MARPOL treaty requesting double hulls, sanctions for non-compliance and network effects can be effective. GHG emissions from forests have also been left out and could be the subject of separate treatment. In manufacturing, the aluminium industry, which is subject to high leakage potential because of the product's homogeneity (see below) is dominated by a few producers and a few countries with only a couple of competing technologies, much like in the case of CFCs emitted by the production of refrigerants. So it might be relatively easy to get a sector agreement similar to the MP: forever with trade sanctions and transfers to help change production processes (from high-emitting Söderberg to low-emitting Prebake technology). Finally, the success of the MP suggests that separate treaties could be applied to different gases.

While implementation might be easier notably because trade sanctions could be better targeted and more easily enforceable, countries could easily wrangle about their respective commitments across treaties as they would feel caught in a straightjacket (making the treaty effective) that would impinge both on sovereignty and on the flexibility of implementation that is offered under the other architectures. As a practical matter, however, it is likely that renegotiation of the entire Harmonized System might be necessary, a task that would meet many hurdles given the present difficulties to agree on the far more modest objective of establishing a list of environmental products for a reduction in tariffs (see section 5). Nonetheless, the WTO has a history of sectoral trade-restrictive agreements, e.g. the Long-term Multifiber Agreement or the Bovine Meat Arrangement.

<u>A Target system with a Carbon Credit Trading System (CCTS</u>*)*. In spite of the difficulties in implementing and monitoring a system on emissions, this is the approach privileged so far under KP1 and likely to be adopted under KP2. The most important argument in its favor, and a very important one, is that if the science is correct, we will have to reduce emissions of GHG gases close to zero (30% of emissions in 1850 were still airborne a century later---Wheeler and Ummel (2008)). The safest way to concentrate on this objective would be to agree on a cap on emissions that, if taken seriously, will focus objectives and mobilize us towards exploring the alternatives to remove our dependency on CO_2-intensive energy. The tax alternative is inherently more uncertain as to its ultimate effects on emissions even though figure 1 shows that emissions are responsive to a hike in the price of fossil fuel. Second, with a CCTS along the lines of an improved CDM, the resource

transfer that is integral to the "common but differentiated" responsibility established under the UNFCC is accomplished without having to go through the tax system which requires a politically-determined budgetary allocation of revenues subject to intense lobbying activities.

Several disadvantages are associated with a CCTS. First, it is likely to lead to greater price volatility. This happened under the SO2 trading system in the US and under the ETS, at least in the initial stages (Ellerman and Joskow (2008), Nordstrom (2009)). Volatility would be particularly problematic because energy is an important budgetary item for firms and households and also for the long-term investment decisions in the Building and Energy sectors. Second, it requires measurement, not of actual emissions, but of emissions of planned projects (potentially presented for strategic motives to obtain the transfer going with the CDM).[6] (If all countries had a cap, the basis of trade and compensation would be made on actual emissions, however generated). Third, there is possibility of strategic behaviour, especially in a system where not all participants face a cap.

The CDM which is at the heart of the KP1 and is inspired from the ETS has been heavily criticized. The 'additionality' principle asks for exclusion of 'win-win' or 'no-regret projects. [7] However a large number of projects in the industrial gas sector have been close to "win-win" projects and have allegedly been subject to gaming.[8] If the transfers under the CDM may have appeared excessive, this does not necessarily mean that the system is inefficient since on efficiency grounds simply the least costly projects should be carried out first. However, it is felt that transaction costs are high

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[6] The CDM has two main objectives: (i) to achieve low-cost emission reductions; (ii) to provide a financial stake for non-Annex I countries to participate in the Kyoto Protocol. It also fulfils a third role of transferring funds without going through the political budgetary process as would be the case with a carbon tax. Various proposals suggest that in the presence of abatement cost uncertainty, permit trading with a safety valve established at the negotiation stage can increase efficiency without decreasing equilibrium participation (Karp and Zhao, 2010). Such safety valves with a price floor and ceiling on the carbon price have also been proposed as a 'collar' to prevent the large fluctuations experienced in the early days of the ETS (see box 2 on the EU ETS).

[7] KP1 defines 'additionality' as any emission-reducing activity that would not occur in the absence of the CDM. The criterion is very controversial since, for example, the 'no-regret' projects which are excluded from the CDM might not be undertaken in financially weak countries. See e.g. Shrestha and Timilsana (2002) and Wara and Victor (2007) for criticisms of the CDM.

[8] Ostrom (2009, p.29.) describes the gaming associated with the 'lucrative' CERs gained from the manufacturers of refrigerants who started producing refrigerants that released trifluoromethane-CFC-23, a GHG just to offset it. According to Wara and Victor (2007), Annex 1 countries paid €4.7 billion for CERs related to CFC-23 a GHG gas whose abatement only cost around €100 million.

and a lot of worthwhile projects are excluded. The lack of transparency and lack of predictability by the Board, and long delays in taking decisions, have contributed to the high transaction costs. Problems of governance have also been pointed out. For example, until recently, the DOE («designated operational entity ») first audited the projects for approval, then verified the emissions reductions for those that he had contributed to approve, creating a conflict of interest (Karp and Zhao (2009)).

3.2. The Political Economy of Implementing a Carbon Price

According to a business as usual (BAU) scenario, average CO2 emissions will be around 10 gigatons in 2025. A recent survey of 18 models comes up with a 100$ per ton tax on carbon as necessary to limit temperature change to 2°C implying $1 trillion in revenues at the global level (Weyant et al. 2006).[9] Whatever approach is adopted, the contestable rents will be huge and of an order of magnitude never seen before in the world economy. We reflect here on two political-economy aspects that have been playing out and are likely to occupy center-stage in the coming years: the preference for an opaque cap-and-trade system where rents will be easy to dissimulate and the capture of trade policy by interest groups under the cover of environmental concerns.

The carbon tax and cap-and-trade in EU and US proposed legislation

Since 1990, Europe has taken the lead in Climate negotiations, being the first to commit to a stabilization target in 1990, then assuming the toughest target in the KP1 negotiations in 1997, and then offering the most ambitious reductions in 2008. With a relatively large disparity in per capita incomes, and energy policies, how did the EU overcome the collective action problem? How did it deal with competitiveness issues carbon leakage and distribution of burdens across members? The EU experience is interesting in several respects. First, although, the Maastricht Treaty extended Treaty-making power to the EU with decision-making on a qualified-majority basis, decisions on energy sources and on taxation remain in the hands of member states so that the EU cannot impose a cap-and-trade system unless there is agreement of all members, nor can it order member states to phase out fossil fuel in favor of renewable energy. Moreover, echoing the principles agreed upon at the UNFCCC,

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[9] Hufbauer et al. (table 1.2) come up with a revenue estimate of 980$ billion for a 100$ tax per ton applied to all countries.

Community policy on the environment has relied on the principle of 'precaution and polluters pay' with common but differentiated responsibilities and respective capabilities since the Council can and has laid down temporary derogation and/or financial support.

BOX 2: The European Leadership on Climate Change

As early as 1990, when the Community planned to cut emissions, it wished to put a tax on fossil fuel intended for heating, transportation and generation of electricity. But countries were reluctant to surrender sovereignty in the tax area, so in 1997 harmonization was then sold as a way to help achieve the Single Market. Yet, as of 2009, the ratio of tax revenues to energy consumption varied by a factor of 5 across the EU. Following the failure of the carbon/energy tax, the ETS which covers less than half of GHG emissions was chosen to meet KP1 targets. A precursor to the CDM, it took inspiration from the trading system in SO_2 emissions under Title IV of the Clean Air Act of the US which put a cap on SO_2 emissions on all large US plant allowing up to 50% of 1980 emissions with permits distributed across plants according to past emissions and trading of permits. Like the ETS (but unlike the CDM), abatement under Title IV was compulsory with a severe penalty. In 2006, compliance was 100%. In the first phase of the ETS cap-and-trade (CAP) scheme (2005-07), emission allowances were allocated for free (contributing through gaming to the over-allocation by 3% as firms overstated their needs). This resulted in large fluctuations and a market price converging to zero in 2007. According to measurements at the installations covered by the cap, emissions went up by an average of 0.24% between 2005-07 (Nordstrom (2009)). In the second phase covering 2008-12 covering the KP1 period it applied to 11,000 firms accounting for about half of CO_2 allowances. Fewer allowances were issued and the price of CO_2 equivalents have been fluctuating between 15 and 25€ per ton. As of late 2009, even though it is uncertain that the KP1 target will be met, it is agreed that without the flexibility mechanism of the JI and CDM, the 2012 target would not have been met.

The ETS is instructive since it addressed the problems facing the renewal for KP2: what sharing arrangement among the disparate EU group would be negotiated and how to implement a cross-border sharing via a CCTS arrangement in which each country was assigned a cap and allocation rights for the largest emitting firms. Early on, in 1995, it became clear that the Community target and burden-sharing had to be negotiated simultaneously. As related by Nordstrom (2009), a bottom-up approach with the economy divided into 3 broad sectors (light domestic sector; energy-intensive export-oriented sector; power-generation sector—the triptique) was adopted. The triptique approach created the needed link between the overall Community target and national sub-targets and also helped implement the notion of 'comparability of efforts' which, along with per capita emissions determined the burden-sharing arrangement (ranging from +16% for Portugal to -16% for Denmark and Germany below 1990 PCE). Also, as under the current proposal for KP2, the percentage cut was conditional on offers by others (15% if other Annex-1 matched the cut, and the final cut was 8% below 1990 by 2012).

For KP2, the Commission started consulting stakeholders as early as 2004. The environmental NGOs wanted the EU to continue leading the way while industry warned against leakage. The council warned about the need to increase public awareness with the European Parliament calling on the Commission to investigate the possibility of leakage and of border measures to mitigate it. Three years were necessary to reach the political decisions to move ahead.

Since the ETS only covers less than half of CO_2 emissions, a sharing agreement had to be reached for residential heating, transport, agriculture and waste management. The sharing formula was close to the one for the ETS, cuts ranging from +20% to -20% from 2005 levels based on a close to linear relation with per-capita income. While countries and stakeholders requested maximum flexibility, a carbon market was also established for non-ETS emissions, but the possibility of transferring abatement between the two markets was denied so that there might be two prices in the carbon market. A mild sanction carrying a penalty of 8% to borrow against future allocations when a target was not met was established.

On the proposals for ETS reforms, close to 90% were against auctioning permits and, if auctioning were to take place, over half in favor of distributing revenues within industries, with opposition the strongest amongst energy-intensive industries. After tortuous negotiations, a final compromise was reached by December 2008 with the EU proposing for COP-15 (COP: Conference of the Parties) a 20% reduction by 2020 from 1990 levels (up to 30% if significant effort is made by others) with sectors exposed to risk getting 100% free allocation up to 2020. The distribution across countries is almost in proportion to their verified emissions and 50% of the proceeds are to be earmarked for mitigation efforts in the EU and in developing countries. As noted by Nordstrom, the leakage issue was so sensitive that heads-of-state could even get involved and that every year the Commission could, at the request of a State, add a sector or sub-sector to the sensitive list (those exposed to risk) that would be eligible to get 100% free allowances.

Box 2 describes major highlights of the negotiations across the EU. Several aspects are noteworthy. First, strong leadership was necessary (here GB, Denmark and other member states) to move forward, suggesting that this will also be necessary in the coming UN negotiations which are now bogged down under the UN process requiring unanimity. Second, in spite of several attempts by the Commission, a carbon tax could not be adapted and efforts at convergence have still a long way to go, since countries are unwilling to give up sovereignty on taxation. Third, an equitable burden-sharing formula largely based on per-capita income (that included 'comparability of efforts') was necessary with the simultaneous negotiation on the cap and the distribution of adjustment. The negotiation process also showed that countries were well aware of their interests.[10] Fourth, financial support was integral (through the free allocation of permits to firms and the redistribution of auction rights under the European Emission Trading System (ETS) with 12 percent of auction rights redistributed to states).

Finally, the issue of leakage was a major preoccupation throughout the debate as early as 1990 and throughout the negotiations within the Community. First, the EU proposals under KP1 and KP2 were conditional on other offers by Annex-I countries reflecting the preoccupation with leakage. Second, provisions for the 'leakage issue' had to be addressed (so far the 'carbon equalization system', has been left out, but at the cost of opening the door to free allowances for many sectors).[11]

[10] As discussed in Nordstrom (2009, sec. 6.4), member states always spoke in their interests (e.g. the reallocation of quota rights to low-income members was welcomed by the low-income members and viewed suspiciously by others).

[11] Permits were allocated for free under the trial period leading to severe criticism (some unjustified-such as free allocation leading to less abatement---see Ellerman and Joskow (2008)). For example, distribution according to past production led to additional pollution while valuable emission rights that were distributed to coal-fired plants were not distributed to firms investing in wind-power. Auctioning with compensation via tightly controlled subsidies would solve these issues, except for the successful lobbying by firms to qualify on the allocation-free list.

In the US also, and for the same reasons as in the EU, a cap-and-trade system enjoys much more support than carbon taxes. Indeed, the majority of bills under consideration reflect this fact (see Hufbauer et al. 2009) with free allowances for critical sectors deemed subject to leakage. In addition to the reasons discussed above, they are painted as entailing little sacrifice from the general public. More importantly, in view of the estimated rents up for attribution under any meaningful restriction on carbon emissions, the holders of licences will have in hand "quota rents" worth hundreds of billions of dollars (estimated at 187$ billion for the US for fuel combustion only for a price of 27$ per metric ton---see Hufbauer et al. (2009) table 1.2).

Recent evidence supports these concerns. First, in a nation-wide representative poll, 75% of Americans responded that global temperature was on the rise due to human activity, with 86% wanting the US government to curb air pollution and 76% wanting the government to limit GHG emissions by businesses. However, confirming the general image that taxes are literally a "tax", 78% opposed taxes on electricity and 72% opposed taxes on gasoline, showing the importance of political pressures against internalization (Jon Kroznik "The Climate Majority", IHT, June 10, 2010). And of the major bills under consideration in the 110th US Congress, only two propose a carbon tax, all the other favoring a cap-and-trade system. For some, like Karp and Zhao (2009), this lack of understanding of economics leads them to propose a CCTS even though it is inferior to a tax on the grounds that it would be "a major mistake to base a proposal for an international climate agreement on the ability to raise this public understanding" (Karp and Zhao, p.16).

Other evidence, however, much in line with the evidence on how EU members negotiated the burden sharing under the ETS, suggests that the public and politicians are well aware of the distributive consequences of a tax. The failed Warner-Lieberman bill offers final thoughts on the political-economy of raising the price of energy. In June 2008, the bill failed a cloture vote (i.e. it fell short of obtaining 60 votes in the Senate). Many observers said that this reflected suppression of evidence on global warming, conservatism, and the lack of public education. However, Wheeler (2008) finds strong econometric support for two concerns evident in the climate change debate: states with heavy fossil dependence will be opposed to the bill; carbon legislation imposed by the rich will inflict a disproportionate burden on poor regions (states). His probit estimates of the vote strongly supports these priors. His simulations suggest that, holding other factors constant, raising income and reducing fossil-fuel dependence would have been sufficient to shift the Senate vote to acceptance. He estimates that a redistribution of 30% of the proceeds through what he calls CASH share certificates (CASH for Certified Atmospheric Share) from the tax proceeds would be sufficient to compensate all families for the rise in energy costs (transportation and housing). But the question is whether the political process would lead to such a redistribution to the households rather than to capture by powerful lobbies.

Further Possibilities for Capture: Energy Subsidies and the environmental Label.
From an environmental standpoint eliminating fossil fuel subsidies estimated at 500$ billion is just as important as any other measure, as recognized by the G-20 leaders in their commitment to slash fuel subsidies that have been captured by the energy industry.[12] However, industries are lobbying hard for rents as seen by the EU proposal for free quota allowances for CO2 permits. This would just be a transfer that will not prevent leakage and could be challenged under WTO law if it were causing adverse effects to the interests of other WTO members.

Another notorious example of capture is bio fuels to reduce dependence on fossil fuels, first implemented by Brazil on the basis of sugarcane starting with the oil crises in the 1970s, and more recently, by the US on the basis of corn. Bio fuels are produced mainly by these two countries. Altogether, bio fuels account for about 2% of global transport fuel. Estimates suggest that sugarcane-produced ethanol reduces GHG emissions by 80% over the cycle of production and corn by only 30%. Furthermore, 1.0 kcal of fossil fuel is estimated to go into 1.12 kcal of ethanol (corn) and 1.38 kcal (sugarcane). According to Hufbauer et al. (2009), 200 support measures costing 5.5$billion to 7.3$ billion are extended each year to bio fuel producers in the US. The US also imposes a 46% percent ad-valorem tariff on imported ethanol as part of US agricultural policy even though supporters invoke the infant industry argument. In the EU, to respond to the desire to substitute fossil by

[12] World Bank (2010) has estimated that removing fossil subsidies in the power and industry sectors only would reduce global CO2 emissions by 6 percent annually while improving economic efficiency.

vegetal fuel, a producer of ethanol is protected by a tariff of 42.9% on imported ethanol.[13]

4. The Role of Trade in GHG Mitigation

Figure 3 splits global CO2e emissions by major sources of emission. Many sources such as power (mainly electricity production) and buildings are non-tradable activities, hence not directly subject to leakage. As to transport, which accounts for 13 percent of total emissions, much is national transport that does not involve trade and only part of industrial production is exchanged internationally (see below). The issue then is how much trade really matters and what is the potential for leakage, a major source of preoccupation in the climate negotiations.

Figure 3: Major Sources of CO2 Equivalent emission of anthropogenic GHGs

Almost all the evidence on the environmental effects of trade has focused on local pollutants. The early evidence (e.g. Grossman and Krueger (1993)), identifies three effects through which trade liberalization may affect the environment.

- a scale effect: increased economic activity from trade liberalization leads ceteris paribus to increased emissions
- a composition effect: trade liberalization may lead to changed specialization patterns across countries and sectors with different emission intensities, which can trigger changes in emissions
- a technique effect: through increased income and technology transfer, trade can lead to cleaner production technologies

But one would like to know the origin of comparative advantage in polluting industries (is it classical factor endowments, energy subsidies or a lax environmental

[13] Ad-valorem tariffs are from Kutas (2010). Hufbauer et al. (2009, appendix B) gives details. Amaral (2008) estimated the following effective rates of protection for biodiesel: Sweden >250%, Germany 149%, France 95%, Spain 69%. It goes without saying that the alternative of mobilizing federal support in the US for the $400 billion necessary to cover a 40 year period to allow solar energy to provide 69% of US electricity and 35% of total energy by 2050 at about the same rates as today does not have much support. See Zweibel et al. (2008). More generally, subsidies in the energy sector should be removed. According to some estimates, the removal of subsidies on fuel would reduce CO2 emissions by as much as 15% (see Strand and Mundaca (2006)).

policy?), and whether those industries may migrate to "pollution havens" with less stringent environmental policies. In the case of KP, would caps among signatories lead to a migration of industries towards non-signatories (or under KP1 to signatories who are not under a cap)? In an open-economy model incorporating trade and environmental policies, comparative advantage in polluting industries is shaped by two forces working in opposite directions:

- a pollution haven effect: laxist environmental regulation in low income countries would give them a comparative advantage in emission-intensive industries
- a factor endowment effect: capital abundance in high income countries would give them a comparative advantage in emission-intensive sectors since they happen also to be capital-intensive

So, the first issue is whether the possibility of trade results in more CO_2 emissions than if there were no trade. For example, is it the case that exporters of chemical products, an energy-intensive sector, emit more than countries that import chemical products? Next, is it likely that energy-intensive industries would migrate if the price of energy were to change differentially across countries as climate change policies are put into place? Finally, how much emissions are embodied in international transport? We examine the evidence on all three issues below.

4.1 Emissions Embodied in Trade

Taking into account indirect emissions via inter-industry linkages, international trade and transport make up roughly 23% of production-based emissions in recent years (see figure 4 and Davis and Caldeira 2010). Figure 4 also shows the emission content of imports and exports from which one can compute a country's Balance of Emissions Embodied in Trade (BEET), expressed a percentage of production-based emissions. A positive (negative) BEET means that the country is a net importer (exporter) of CO_2 emissions in its trade bundle. Developed countries are net importers (e.g. -7% for the US, and -16% for Canada). Developing countries on the other hand are net exporters of emissions, with China, South Africa, Venezuela and Malaysia having positive BEETs above 15%. Other estimates indicate that China's net embodied emissions and energy content has been increasing between 2001 and 2006

(Pan et al. (2008)). Although BEETs are not a direct measure of leakage (see below), these patterns, especially those for China, suggest the possibility of carbon leakage.

Figure 4 here: Embodied emissions in imports and exports

4.2 Estimates of Carbon Leakage

Leakage effects (known as the 'pollution haven' effect in the trade and environment literature) during reduction in GHG emissions come about through two channels.[14] First, emission-intensive industries could simply relocate to countries, where policies are less stringent (the pollution haven effect mentioned above—see e.g. Copeland and Taylor (2003)). This effect can take place either through a reallocation of market shares or through increased investment towards unconstrained industries. The second effect is indirect. By increasing the cost of emission-intensive goods through climate policy, the derived demand for carbon intensive inputs (e.g. oil) is reduced reducing potentially the price of oil on world markets. This indirect effect would also shift comparative advantage towards countries that are not implementing a climate policy. In both cases, the effectiveness of GHG mitigation would be reduced.

Instructive predictions about the likely effects of a rise in the price of carbon can be gleaned by looking at the case of SO2. SO2 is responsible for acid rain, a regional phenomenon. SO2 and CO2 (emission) intensities are in fact highly correlated across industries. The coefficient of correlation is higher than 0.9 for UK industries for the average over 1990-2000 (see table 1). Not surprisingly, the same six industries are the main emitters for both gases: petroleum products, pulp and paper, non-ferrous metals, iron and steel, chemicals, building material – cement). These are energy-intensive industries and hence heavy emitters of CO2. Therefore it is worthwhile to review studies based on SO2 and other energy-intensive industries to get a feeling for the likely leakage under implementable climate change mitigation policies.

[14] carbon leakage rate = (increase in emissions due to climate policy *outside* enacting country/decrease in emissions due to climate policy *in* enacting country)

Table 1 here: Comparison SO2 and CO2

First, the more tradable among these sectors are largely weight-reducing industries. Smelting non-ferrous metals (and the processing of paper from wood) usually takes place close to extraction sites to avoid transport costs. Grether and de Melo (2004) estimate a bilateral trade gravity model for each one of these dirty industries and an aggregate of 'clean' industries and find a consistently higher coefficient for the distance coefficient for dirty industries (in the range -1.10 to -1.40 except for non-ferrous metals estimated at -.95 while the average for clean industries is -0.82)[15]. This, and the fact that extraction in natural-resource based industries cannot migrate, would suggest that transport costs would deter relocation of much processing to countries with lower regulation standards.

Other work has also tried to detect pollution-haven effects in the case of SO2 where national attempts at controlling acid rain could have led to leakage. Using concentration data, Antweiler, Copeland and Taylor (ACT(2003)), estimate that if an increase in trade openness generates a 1% increase in income and output, then pollution will fall approximately by 1%.[16] Drawing on an extensive data base covering the same six sectors and a 'clean' sector for 62 countries with emission coefficients for 1990 and 2000, Grether et al. (2010a) decompose changes in world SO2 emissions. The scale effect accounted for a 10% increase in emissions while the shift towards cleaner industries within (across) countries accounted for a decrease in emissions of 2% (3%) and the technique effect accounted for a decrease in emissions of 14%. As a result, while manufacturing growth was 8% over the decade, SO2 emissions fell by 10% or 1% per annum, about half of the needed reduction in emissions for the OECD countries projected in figure 2 for a convergence in CO2 emissions over a fifty year period.

[15] A distance coefficient estimate of –1.40 [-0.95] implies that if trade flows are normalized to 1 for a distance of 1000km, a doubling of distance to 2000 would reduce bilateral trade volume to 0.38 [0.52]. On the basis of US data, Ederington et al (2005)) also come to the same conclusion that these same polluting industries are not footloose.

[16] Applied to CO2 emissions, the ACT framework suggests that trade is likely to increase emissions in the case of carbon dioxide (Cole and Elliott, 2003). Managi et al (2009) find that trade has a beneficial effect on emissions for OECD countries, but a detrimental effect for non-OECD countries.

Figure 5 here: Decomposition of SO2 Emissions 1990-2000

Figure 5 gives the details of this decomposition across industries and across countries. Only non-ferrous metals had an increase in emissions per unit of output. Between-sector and between-country effects contributed to a reduction in emissions. Particularly noteworthy is the absence of leakage effects for the US (the mandated reductions in SO2 and the emission trading system entered into effect in 1996). In sum, insofar as SO2 is comparable to CO2, SO2 estimates suggest that leakage effects would be small. In addition, reduction in emissions came through the technique effect, pointing towards the (obvious) necessity to develop clean sources of energy in the struggle to mitigate CO2 emissions.[17]

It could be objected that costs associated with energy or environmental regulation are small in overall costs explaining the negligible relocation effects for SO2, costs that would be much higher with any realistic carbon price under CO2 mitigation. Yet, other ex-post econometric estimates trying to disentangle the environmental effects from other determinants of bilateral trade volumes across a broad range of manufacturing activities have also failed to detect significant effects.[18]

A different picture emerges from the ex-ante work on CO2 emissions. Table A1 in the annex reviews the results from these studies, either industry partial equilibrium or general equilibrium estimates. Most are concerned either with the leakage rate resulting from the application of a carbon tax or with the efficiency of border tax adjustments (BTA) to dampen leakage. A glance at the last column of table A1 shows that estimates vary greatly across studies and across sectors. There are several reasons for these discrepancies. For example, electricity is non-tradable so it will not be subject to direct leakage, although indirect effects are at work in energy-intensive

[17] Levinson (2009) also carries out retrospective calculations for the US over the period 1972-2001 using US emission data for 1997 and input-output data to capture the indirect SO2-content for imports. Although his data do not allow him to capture technical change in emissions nor changes in emissions due to a within-sector shift towards producers with higher per-unit emissions, he also finds a strong compositional effect away from the production of SO2-intensive manufacturing activities coupled with a shift away from SO2-intensive imports over this longer period of time.

[18] In a gravity-type framework separating fundamental from environment-related factors influencing the volume of bilateral trade, Grether et al. (2010b) estimate that for a large number of pollutants (SO2 included), pollution haven and factor endowment effects mostly cancel each other out.

sectors (see column 2 of table A2). To take another extreme example, aluminum can be considered very tradable in the sense that aluminum products from different origins are very close substitutes--in the limit, aluminum is homogenous like white sugar. Thus switching from the standard imperfect substitution assumption universally embodied in the "Armington" assumption to one of perfect substitutes along with increasing returns to scale (rather than a constant returns to scale technology) in an otherwise standard multi-region general equilibrium (MR-GE) model increases the leakage rate of meeting the KP1 emission targets in that sector from 20% to over 100% (see table A1). High leakage rates above 30% are also obtained in linear-programming estimates with a large number of processes when domestic and foreign-produced goods are assumed to be perfect substitutes. Note further that most MR-CGE models predict that carbon leakage mainly works through interaction in world energy markets (second channel mentioned above) and that for this channel, the comparison with SO2 is rather weak (see Gerlagh and Kuik, 2007).

Once one adopts the standard imperfect substitute assumption, leakage rate estimates fall substantially. In the MR-GE models, in the absence of a border tax adjustment, estimated leakage rates are in the 10%-20% range. The importance of participation comes out clearly when leakage rates are compared under different participation scenarios. If the EU (or the US) cut emissions by 20%, the leakage rate is around 35% but it is only 20% when both cut emissions together.

These models also provide estimates of the effects of border tax adjustments (BTA) to prevent carbon leakage (the legal aspects of the introduction of border measures are discussed in section 5). MR-GE estimates suggest that a border tax adjustment will reduce leakage by half. The reason of the relative inefficiency of a BTA is that tax on the CO2 content of imports has a strong terms-of-trade effect in favor of the country that imposes the BTA thereby leading it to increase its volume of imports. The models also give estimates of the different BTAs that have been proposed in the political debate. One of the proposals circulated in the US would be to adjust the price of imports by applying the CO2 tax in the US to the total (direct and indirect) carbon content of imports, perhaps along with a relief from paying the tax for exporters. Another proposal would be to tax imports on the basis of the carbon content of imports (US legislation allows to oblige importers to buy emission allowances equivalent to the carbon content of imports). Mattoo et al. (2009), estimate that if industrial countries reduce emissions by 17% without applying a BTA, manufacturing exports by developing countries remain unchanged but fall by about 2% under the first proposal, and by 15% under the second proposal. Should developed countries try to impose across-the-board taxation on imports based on their carbon content, there would be a collision between developed and developing countries at the WTO.

While these model-based estimates are transparent and are arguably the best game in town so far, they differ sharply from the few econometric and ex-post studies. When simulating the output response to energy prices using econometrically estimated elasticities for a large sample of industries in the US, Aldy and Pizer (2009) obtain very small effects from the imposition of a 15$ ton tax on carbon. On average, production goes down by 0.6% and the competitiveness effect (defined as the difference between the consumption and production effect) is a negligible -0.2%. Ex-post analysis of CO_2 price data for 1999-2006 for the EU ETS did not reveal a structural change in trade flows (Reinaud (2008)). A similar finding was obtained for the refinery sector (Lacombe (2008)). However, because prices for CO_2 permits remained low under the ETS notably because of over-allocation, these results may not be informative.

Drawing on data for 38 countries (26 of which have ratified Kyoto), and 12 sectors over the period 1995-2005, Aichele and Felbermayr (2010) estimate the impact of different GHG policies on trade flows and emissions. They estimate that carbon imports are on average 12% higher if the importer has ratified Kyoto and his trading partner not. Confirming previous work, the effect is most important in energy intensive industries, where robust evidence for carbon leakage was found for seven sectors. Their findings suggest that, even though the volume of trade "caused" by Kyoto is rather small, on average about 40% of carbon savings due to the ratification of the Kyoto protocol has been offset by increasing emissions in non-committing countries.

We said earlier that an open world economy is important to facilitate technological transfers. Di Maria and van den Werf (2008) and Acemoglu et al (2009) argue that effective long run carbon leakage might be smaller than the results from the above studies, because induced technological change might have a positive effect. Using panel data in a gravity model, Mazzanti and Costantini (2010) analyze the effect of energy and environmental policy in the EU on export dynamics of four sectors over the period 1996-2007. Including patent data, they find evidence that the overall effect of energy policy is not in conflict with export competitiveness. Overall, these results support the Porter hypothesis (Porter and van der Linde 1995), which states that stricter environmental regulation can have a 'halo' rather than a 'pollution haven' effect by inducing efficiency and encouraging innovation.

Because we have not yet experienced a sufficiently important increase in the price of carbon, it is difficult to get a sense of the likely magnitude of leakage. However, even if as argued above leakage may not be as high as those suggested by ex-ante estimates, pressures for border tax adjustments have already surfaced and will intensify as the price of carbon increases.

4.3 The Environmental Consequences of Transport

Transport costs (national and international) account for approximately 13% of global CO2 emissions (about two-thirds of emissions related to manufacturing activity) with shipping-related emissions raising particularly strong concerns. Shipping now accounts for about 90 percent of the volume of global trade and about 3 percent of global CO2 emissions. In addition, oceangoing ships use bunker fuel and emit about 15 percent of global nitrogen oxides and between 5 and 8 percent of global sulfur oxide emissions, regional pollutants contributing to respiratory illnesses, cardiopulmonary disorders and lung cancers, particularly among people who live near heavy ship traffic (70% of emissions are within 400 km of land). With the relocation of manufacturing activity to Asia, shipping volume has increased by 50% over the past 20 years. [19] Short of increasing the cost of fuel for long hauls so as to

[19] IHT April 26,2010 "Controlling Pollution from Ships". Maersk has reported that it is cutting speed in half reducing fuel consumption and emissions by 30%. Bunker oil costs half the price of cleaner oil. The US EPA estimates that applying a 400 km buffer zone along Canadian and US coastlines would save up to 8300 lives a year by 2020. However, to arrest the increase in shipping emissions, fuel costs on long-distance hauls has to increase to the point where shippers change location supply so that trade patterns back to the 70s before goods were produced in Asia and consumed in Europe. As expected, there was a strong opposition from Asian exporters to the proposal of a tax on fuel for shipping by the EU even though the proposal stated that the proceeds would be rebated to developing countries (IHT, March 2, 2010 "IMO Seeks emission cuts for emerging-nation ships")

change the location of supply, what are the emission implications of international trade? How much then does international trade contribute to CO_2 emissions?[20]

Two recent estimates provide orders of magnitude for a large number of countries. Hummels (2009) uses the GTAP model to estimate that full trade liberalization would increase trade volumes by 5.8%. He then converts this growth into weight-distance profiles by modal usage (truck, air and maritime) to which he applies GHG emission estimates. His results show a shift in trade away from close to distant partners and estimates that CO_2 emissions could increase by as much as 10%. So insofar as trade liberalization is likely to involve growth at the extensive margin (new partners), it is not friendly to the environment. Hummels estimates would thus suggest an elasticity of emission to trade growth of around 1.5.

Grether et al. (2010a) carry out a similar exercise for worldwide SO_2 emissions over the period 1990-2000 during which manufacturing output grew by 8%. They first define an anti-monde in which countries produce what they actually consume in the trade equilibrium and find that international trade increases emissions by 10% in 1990 and only by 3.5% in 2000, largely a reflection of the all-around decline in emission-intensity. Using a rough decomposition by mode of transport, they estimate that international-trade related emissions accounted for about 5-9% of total manufacturing emissions. Adding trade and transport-cost related emissions, their estimates suggest that transport-related emissions have gone from accounting for roughly one third to three quarters of total trade-related emissions over the 1990-2000 period. To put it differently, if one adds up emissions coming from trade-related composition effects and trade-related transport activities, one obtains that global worldwide manufacturing emissions are increased through trade by 16 percent in 1990 and 13 percent in 2000.

Both sets of estimates are only rough orders of magnitude. Carbon footprint estimates should factor in that favorable climatic conditions and the use of low energy-intensive production technologies in developing countries may lead to carbon efficiencies that outweigh additional emissions due to transport for products shipped

[20] International transport is only a fraction of transport. Cadarso et al (2010) estimate that international trade accounts for 4% of transport embodied in Spanish consumption.

to and consumed in developed countries[21]. Reducing trade-related GHG emissions would be best achieved by an agreement on transport that would impose low-emitting technologies (e.g. hydrogen). Short of such an approach, raising transport costs by taxes on transport will reduce trade, measures that will reduce GDP growth. On the other hand, if externalities were corrected where they occur (i.e. in the GHG emitting sectors rather than by raising taxes on trade), then world welfare would increase.

5. Climate Change and the WTO

For the international community there are two broad strands of discussion. On the one hand there are fears that the large gains from trade could easily be eroded by trade policies seeking to counteract spillover effects from climate change mitigation measures. On the other hand, there is widespread agreement that subsidies to energy and to substitutes to fossil fuels (e.g. to biofuels) should be removed. Here we focus on the interface of climate change and the WTO. First, are WTO rules and previous dispute settlement at the WTO adequate to deal with the pressures to apply border measures to counter leakage towards non-participants? Second, how much progress is there on liberalization of tariffs on environmental goods and services?[22]

5.1 Border Measures to Address Leakage Concerns

By changing carbon prices across countries, climate policies will lead to demand for border adjustments to address competitiveness effects. Indeed, proposed US legislation (the Warner-Lieberman and Waxman-Markey bills) included the possibility of border adjustments for energy-intensive industries that would loose competitiveness to countries that would not enact a similar policy. Such pressures have already appeared under KP1 against non-signatories (semi-finished steel, clinker, aluminum, cement and some basic chemicals).[23]

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[21] Brenton et al (2009) survey results from carbon-accounting and carbon-labeling studies involving developing countries.

[22] The UNEP/WTO 2009 report covers these issues in greater depth.

[23] President Sarkozy of France proposed a border tax adjustment on American exports to the EU because they did not participate in the KP1. It was a great cost in terms of concessions to industry

As pointed out in section 3, ideally, a worldwide price on greenhouse gas emissions (through a tax or an emission trading system) should be applied at the social marginal cost of the latter. This would allow internalizing external costs, such as negative effects of emissions that are not taken into account by individuals, since property rights are badly defined when it comes to the world's climate.[24] However, as long as emitting activities, such as burning coal, oil and gas are not subject to a cost internalizing these negative effects in some countries (i.e. the non-signatories of the KP), energy-intensive industries are implicitly subsidized. The WTO provides for a number of disciplines that regulate the use of subsidies that could come into play in this context. Thus, non-signatories of KP1 like the US are in effect enjoying an unfair trade advantage that Kyoto signatories could bring to the WTO. Given that a single world-wide price on greenhouse gas emissions is not politically achievable, there will be a call for border adjustments for the climate-induced change in competitiveness among WTO members.

Thus much of the debate on the relation between trade and the environment revolves around a "border adjustment" to bring about a level playing field across countries in energy-intensive industries following differential efforts at reducing emissions. Another motivation would be leverage, in the sense that the threat of border adjustment could be used to force countries to participate in climate negotiations. While the first motivation calls for trade controls, the second calls for trade sanctions. The focus here is on trade controls, applied to environmentally relevant sectors, as opposed to trade sanctions, where targeted products are unrelated to environmental discrepancy (Charnovitz, 2003). In the case of Kyoto, no trade measures were included in the treaty, while in the Montreal protocol, trade bans were included from the beginning in the agreement as an instrument to achieve the goal of full participation in the treaty.[25]

(quasi-automatic access to free allowances) to obtain that border tax adjustments would be left out of the EU proposal for the KP2.

[24] Allocative efficiency would be achieved when marginal abatement costs (MAC) would be equal to the marginal social costs (MSC) of abatement. And if the same price applies everywhere, worldwide efficiency would be achieved. But it is very difficult to estimate with any confidence the social cost of carbon as it requires estimating the marginal damage from an extra unit of carbon which depends on assumptions about the future path of the economy, the discount rate, science, etc…

[25] e.g. Frankel (2009). In fact the variable of concern under the Montreal Protocol was consumption, defined as "production-exports+imports". Hence trade flows were directly included.

From an economic point of view, if the externality in production were corrected via a tax on carbon, any tax imposed at the border would lead to inefficiencies, since it would lead to trade diversion in the sense that countries without stringent climate policy would shift their exports to countries that do not apply any kind of adjustment at the border. For example, in the EU where the tax on gasoline is about four times as high as in the US, a border tax on EU imports from the US, would create an inefficiency in terms of diverting American export to other countries.[26]

Hence the thorniest issue for the functioning of the World Trade System is how the conflicts from different carbon policies will be resolved. Would trade intervention justified by differences in climate policy be allowed under WTO law?[27] So far, this is uncharted territory in spite of several environmental cases that have been settled by the dispute settlement process. The answer depends crucially on the specific design and implementation of the intervention. Generally, two types of trade measures could be imposed on imports to complement mitigation policies. Restrictions could be with respect to "locally emitted" greenhouse gases or with respect to "foreign emitted" gases. In the first category, emissions take place when the imported goods are "consumed". Emission standards on cars would for instance fall in this group. Pauwelyn (2007) states that if such measures do not discriminate imports against local products, they generally should be accepted under WTO law.

If, however trade restrictions address greenhouse gases of imports that are emitted in the trading partner country (embodied emissions in imported products during their production in the foreign country), compliance with WTO law is more controversial.[28]

[26] As an example, since 2007 China has implemented export tariffs ranging from 5 to 25 percent on carbon-intensive products including iron, steel, coke and cement, so the US should not seek to impose a BTA. See the comment by Hu Tao in Brainard and Sorkin (2009).
[27] Relevant environmental WTO cases are: US-Gasoline, US-Shrimp and Brazil-Retreaded Tyres. In a first decision by the appellate body in the Tuna-dolphin case involving the US and Mexico (under the GATT (1991)), the US lost the case when it argued that tuna could only be imported if it was caught in purse-seine nets, jurisprudence that was overturned later in the shrimp-turtle decision which in effect allowed that process and production methods (PPMs) could be invoked at the WTO for contingent protection. Technically the shrimp-turtle case did not explicitly approve the so-called non-product related process and production methods (NPR-PPMs), but as a results of the case, it could under certain circumstances be justified under the GATT's article XX exception clauses.
[28] Following Pauwelyn (2007) three measures in that category are most likely to violate international trade law. Import bans or punitive tariffs would violate Article XI of the GATT, which imposes the elimination of quantitative restrictions, but also article I which states that discrimination between imports from different countries must be avoided. The same holds for contingent measures that would

An example would be imported aluminum produced with high CO_2-emitting Söderberg technology. Consider then the application of a border tax adjustment (BTA) on imported aluminum[29]. Could it be defended under international trade law? Yes, if it were possible to convince the WTO panel that the imposed competitiveness provisions are only an extension of domestic climate policy applied on an equal footing to imports. We illustrate the difficulties in the case where one country (B in figure 6) enacts a greenhouse gas tax and its trading partners (A in figure 6) do not have an equivalent climate policy. Note that carbon leakage must take place, since arguments purely based on losses of domestic firm's competitiveness will not be considered as relevant. The idea is to apply at the border a charge equivalent to an internal tax and conversely one could rebate the same tax on domestic products that are exported (this was the practice under the application of the VAT). Figure 6 shows the two main possibilities on how such a trade intervention could be justified under WTO law.

Figure 6 here: Justifying Border Measures under WTO law

To be applied, it must first be checked if the BTA on imports is covered by GATT Articles II (tariff obligation which requires members to fix tariff levels at bound rates) and III (national treatment, i.e. not to apply internal taxes to protect domestic producers). Such BTA restrictions are not only covered by GATT Article II on tariffs but also by GATT Article III:2 on domestic taxes. In a nutshell, the instrument against which adjustment is requested must be an indirect product tax (e.g. value added tax, excise tax, ...) and not a direct producer tax (e.g. payroll tax, income tax, ...) and that it must be non-discriminatory (see below). As discussed in Demaret and Stewardson (1994) under GATT Article III.2 border adjustment is allowed under taxes "applied directly or indirectly to like domestic products". The crucial question

also likely violate WTO law. According to Pauwelyn (2007), anti-dumping duties against "environmental dumping" could only be levied if import prices are below the prices in the country of origin. This is not a measure adapted to address competitiveness concerns emanating from different climate policies. And countervailing duties to offset the de facto "subsidy" of imports in their country of origin are the third measure that is likely to violate WTO law. Several conditions are necessary to show that the government "fails to act" i.e. to impose a carbon policy instrument, to be allowed to impose countervailing duties. Most importantly, not imposing a climate policy is not likely to be considered as either a specific subsidy (specific to group of enterprises or industries) or an export subsidy.

[29] Other measures could also take the form of mandatory allowance purchases by importers or embedded carbon product standards.

then is whether this applies also to inputs that are physically not incorporated directly (such as greenhouse gas emissions released during production) in the final product. It has been argued that the GATT *Superfund* case[30] confirms that BTAs are possible for inputs that are not physically incorporated in the traded product. Under the presumption that the BTA can be justified under Articles II, III GATT, then the adjustment must meet the WTO principles of national treatment (NT—article III) and most-favored-nation (MFN—article I).

If the above-mentioned justification for imposing trade restrictions were not allowed (left-arm in figure 6), violation of GATT Articles II, III is still possible if environmental exceptions under Article XX GATT can be invoked. Paragraph (g)[31] is the key article related to the environment and it asks for three cumulative conditions likely to be satisfied. First it has to be shown that the planet's atmosphere is an exhaustible natural resource. Second, it has to be shown that the given climate change policy as a whole has a "substantial relationship" with the conservation of the atmosphere. And third, broadly similar conditions must be imposed on domestic producers. According to Pauwelyn (2007), and the latest scientific evidence, the first two conditions should be easily met, and a standard carbon tax, should also meet the third.

However, to be WTO-law compatible, an adjustment at the border must also satisfy the conditions under the introductory (chapeau) phrase of Article XX GATT. So far, whenever the Appellate Body found that the GATT XX exception was not met, it did so under the introductory phrase. More specifically three elements are important. First, the legislation has to take into account local conditions in foreign countries. On the one hand, there are other ways to address climate change, and on the other hand developing countries may not be asked to carry the same burden of adjustment as industrialized countries. Second, before having imposed the unilateral trade restriction, the country must have previously engaged in serious across-the-board negotiations with the objective of concluding a bilateral or multilateral agreement.

[30] In the case of the GATT Superfund, the dispute panel found that US taxes on 'chemicals used as materials in the manufacture or production of the imported substances' might be taken into account when imposing border tax adjustments on imported like products.
[31] The defendant party could also invoke paragraph (b) in article XX which is more difficult to be fulfilled as it asks for a closer link between the measure and the environmental goal. It reads: (b): "necessary to protect human, animal or plant life or health".

Finally, the implementation and administration of the imposed trade policy has to respect basic fairness and due process. For example, concrete problems, like delayed imports related to border controls should be avoided. Jurisprudence has highlighted the importance of flexibility in the design of the measure, to take into account different situations in different countries.

In sum, the conditions related to the introductory phrase of Article XX GATT are still highly controversial for leakage effects arising from cost differentials related to differential costs due to different energy and environment policies. Notwithstanding the recent environmental disputes that have been adjudicated by the WTO, it is easy to imagine that leakage concerns will be subject to extensive litigation.

In the case where an emission trading system (ETS) is enacted instead of a carbon tax, concerns discussed above are also raised, but in addition it must be shown that the obligation to hold permits is equivalent to an internal tax since it is also imposing a cost on firms if these have to be purchased by the firms. Moreover if some permits are handed out for free, instead of being auctioned off, some kind of average market price would have to be used, to determine the level of the effective cost and hence the tax. Ismer and Neuhoff (2007) investigate conformity and feasibility of a BTA for an emission trading system. They propose an adjustment level that does not exceed the upper bound of the amount payable for production in the country enacting the emission trading system using the best available technology.

Several other problems lurk at the horizon. To begin with, as pointed out by several papers[32], the implementation of such border adjustment with respect to embodied carbon would be very costly.[33] Indeed, Ismer and Neuhoff (2007) say that only an indirect scheme, using a measure highly correlated with effective embodied carbon emissions, would be implementable. They suggest to use specific input mixes and to multiply these quantities with emission coefficients. A special case is electricity, where the mix varies considerably between countries and therefore contains very different levels of embodied emissions. Moreover, since exporting countries would be unlikely to truthfully cooperate in the computation of the carbon content of their

[32] e.g. Bhagwati and Mavroidis (2007),

[33] In Messerlin's (2010) words: one would need a gigantic database, generating astronomical transaction costs and the risk for corruption would be huge.

products, Pauwelyn (2007) has suggested for this case to compute an implicit carbon content based on production techniques dominant in importing countries. Ismer and Neuhoff (2007) propose a processed-material approach with best available technology.

Still, implementing such a scheme would be a nightmare, even more so for developing countries, as ample experience on the less controversial tax rebate for tariffs on imported inputs in free trade zones has shown. Further, BTAs may open the door to capture by powerful domestic political interest group and be the source of disguised protection. Finally, imposing carbon tariffs could be seen as leverage to induce countries to participate in climate negotiations but, more likely, it could undermine trust between trading partners, and would poison the hard-to-acquire trust in the multilateral negotiations and endanger future agreements.

In sum, even if carefully constructed and implemented border measures could in theory pass WTO law, political-economy considerations suggest that it might not be a good instrument to level the playing field for energy- intensive industries. Pauwelyn (2007) puts forward several other instruments that might be used instead. As discussed above in section 4, a country that adopts an ETS can alleviate competition effects by adopting flexibility mechanisms (such as the clean development mechanism (CDM) under the Kyoto Protocol) that allow companies to trade emission permits and hence reduce abatement costs. Other possibilities are free distribution of all (or at least part of) emission permits or exclusion of industries that are most exposed to international competition from stringent emission reduction programs. The problem with this measure is that it is in effect a subsidy that could be actionable under GATT law (i.e. it does not follow the polluter-pays principle and it might create windfall profits for highly polluting industries). Also, safety-valves could be imposed thereby assuring companies that permit prices would not exceed a maximum price.

5.2 Liberalization of Environmental Goods and Services

Under the 2001 Doha Ministerial Declaration, WTO members have been asked to negotiate on the reduction, or, as appropriate, elimination of tariff and non-tariff barriers (NTBs) on environmental goods and services (EGS).[34] The aim is to create a triple win situation, for trade, the environment, and for development. If negotiations were successful, trade would be facilitated through a reduction or an elimination of tariffs and NTBs on EGS. The intension is to decrease costs of environmental technologies, increase their use and stimulate innovation and technology transfer.

Developing countries would benefit in two ways from better market access in EGS. Producers of environmental goods and services would have better access to large markets in Europe, the US and high income Asia and it would be easier for developing countries as a whole to obtain high quality environmental goods on world markets. Such access could for instance increase energy efficiency and improve the water and sanitation situation in developing countries. Increased trade in these products would lead to overall welfare gains and would help developing countries reduce emissions through technology transfer.

Even though liberalization in these particular product categories should be 'win-win', WTO members have been unable to agree on which goods should be liberalized. Three approaches have been proposed to identify these goods. In the *list approach,* WTO members would have to agree on a list of products (at HS 6-digit level) for which trade barriers should be reduced. So far WTO members have been unable to agree on such a list. Developing countries argued that a number of products on the list are of export interest primarily to industrialized countries. Also problematic is the issue of *dual use* as many product categories proposed (at HS 6-digit level) include also products that also have non-environmental uses. It would be possible to select "ex-outs" (goods which are not separately identified at the 6-digit level of the HS and have to be identified in national tariff schedules at the 8- or 10-digit level) but this would be particularly costly and difficult for developing countries. In response to this issue, India and Argentina proposed a *define-by-doing approach* where national authorities would select projects. Environmental goods and services necessary for the selected projects would then temporarily benefit from enhanced market access. Categories of goods could be identified multilaterally in advance. Finally, Brazil

[34] Negotiations take place in the Special Session of the Committee on Trade and the Environment (CTE in Special Session). The Doha negotiations also address the question of the relationship between the WTO and multilateral environmental agreements (MEAs). For more on the link between the WTO and MEAs, see WTO-UNEP (2009), pp. 82-83.

suggested a *request-offer approach*. Under this approach, countries would request specific tariff cut commitments on products of interest and then extend these tariff-cuts to all WTO members based on the MFN clause. Such an approach might better take into account developing countries' specific interests.[35]

Including all HS-6 tariff lines that have so far been proposed in the lists officially submitted to the WTO[36] EGS make up about 20% of total trade value. Developing countries account for about 40% of EGS trade, with 40% of imports and 42% of exports. Concerning tariffs, however, there is a clear difference between countries depending on income levels. Developed countries have MFN tariffs below 2% on average whereas low-income developing countries and developing countries have average MFN tariffs of 11% and 6% respectively. Overall, the trade and protection pattern in the tariff lines submitted for EGS negotiations seem to be very similar to the overall pattern.

The triple-win expectation from a liberalization of trade in EGS has been challenged. Consider a vertical industry where the downstream good's production is polluting and the upstream industry that faces international competition is engaged in R&D to develop abatement technology that it can sell to the downstream firm. In this setting, Dijkstra and Mathew (2009) show that it might be best for developing countries to first liberalize trade in environmental goods with countries whose environmental technologies are not too much better than their own. This would stimulate R&D in the domestic eco-industry putting it in a better position to face competition from more advanced eco-firms later. They also show that when cleaner technologies become available, governments have an incentive to reduce the effective tax on polluting output to take the opportunity to increase welfare through increased profits of the downstream firm and increased consumer surplus. Hence they show that liberalisation in environmental goods and services might lead to a situation where

[35] One could also classify EGS along a different dimension. 'Traditional' environmental goods are goods whose main purpose is to treat a specific environmental problem (e.g. wastewater treatment equipment). A second, broader type of goods relates to the so-called 'environmentally preferable' goods (EPPs). For each EPP there exists a close substitute with a similar use but which is less environmentally friendly. An example of an EPP is an energy-efficient washing machine. Another that is most doubtful, is the use of biofuel to save on energy and reduce CO_2 emissions.

[36] Four submissions have been made: a group of 9 members (Canada, EU, Japan, Korea, New Zealand, Norway, Switzerland, Chinese Taipei and United States), Saudi Arabia, Japan and the Philippines.

consumer benefits come at the expense of the environment. Next consider an environment where the North innovates and technologies diffuse to the South. In a stylized model, Di Maria and Smulders (2005) investigate the role of endogenous technology and technology spillovers. They conclude that endogeneous technological change is potentially but not necessarily a blessing. The lack of intellectual property rights in the South and innovations costs asymmetrically born by the Northern consumers create distortions.

There is little evidence on the effects of liberalization of EGS. Using a partial equilibrium simulation model applying import elasticities to trade data for the eighteen most important developing country emitters of GHGs, World Bank (2008) assessed the effect of trade liberalization (tariff and tariff NTB elimination) for the following four technologies: clean coal technologies, wind energy, solar photovoltaic systems and energy-efficient lighting. Eliminating trade barriers would increase import volumes by up to thirteen percent. More generally, Dechezleprêtre et al. (2009) used patent data from 66 countries for the period 1990-2003 and investigated driving forces of transfer of climate change mitigation technologies. Their regression results show that restrictions to international trade (treated as an exogenous variable) influence negatively the diffusion of patented knowledge. However, Managi and Kumar (2009) estimated exogenous and trade-induced technological change for 76 countries over the period 1963-2000 and found that the trade induced technological change, which makes up roughly one third of overall technological change had a negative effect on GDP and increased pollution.

The lack of progress on negotiations on EGS could be attributed to traditional fears invoked by developing countries to protect sectors from international markets dominated by industrialized countries. Infant industries would then deserve temporary protection. Also, if a first mover advantage or lock-in-effects exist, then developing countries may have incentives not to liberalize these markets too quickly. Finally, negotiations of environmental goods and services are only a secondary arena in the Doha negotiation round. It might well be that developing countries are using the negotiations in environmental goods and services as a leverage to better defend their interests in the agricultural negotiations where developing countries have greater interests at stake.

6. Final Reflections: Lessons from World Trade for Governing Climate Change

Reflecting on the Rio outcome, as KP1 was under negotiation, Prime Minister Bruntland said: "We knew the Basic Principles on which to build: cost-effectiveness, equity, joint implementation and comprehensiveness. But not how to make them operational" (Cited in Schmalensee (1998)). Fifteen years later with KP1 nearing its end and negotiations for KP2 under way what have we learnt? Certainly one would add that cost-effectiveness has to go beyond flexibility mechanisms: it requires participation and compliance as shown by the success of the MP (see box 1). Are there any lessons for the design of climate-related trade policies from the evolution of the World Trading System, first under the GATT, then under the WTO?

<u>An umbrella agreement with leeway.</u> Looking back at the early days of the GATT, participation was among a small group of countries where negotiation was easier than under the now unwieldy WTO where unanimity is required for all major decisions. The GATT thus made progress towards free trade with agreements that bound nations in ways that did not impinge on their national sovereignty. As proposed by Antholis (2009), taking their inspiration from the GATT, climate negotiators could set up a General Agreement to Reduce Emissions (GARE) avoiding to move too quickly into a full-blown organization like a World Environment Organization or a Treaty under the UN process which also requires unanimity.

It is noteworthy that under the GATT, sustained national tariff cuts took place without the appearance of the loss of sovereignty with much tariff reduction taking place unilaterally. Adjudication and dispute settlement could evolve progressively as it did under the GATT/WTO so that fears of loss of sovereignty would be alleviated (under the GATT, a panel decision against a member could be blocked by the member).

What should be the principles for an umbrella Climate code? There is broad agreement among commentators. [37] Carbon taxes should be encouraged, though not

[37] Frankel (2008), Hufbauer et al (2009) and Messerlin (2010) are the main recent commentators on a Trade and Climate Code.

required, auctioning of permits should likewise be encouraged, trade-related GHG measures should be limited, like products should be defined at a broad enough level of aggregation (4-digit HS for Hufbauer et al.) and the modalities for border adjustments and the management of a CAT should be flexible. Countries that would subscribe to this "green code" would benefit from a "peace clause" so as to avoid being subject to WTO disputes. It is likely however, that this sensible approach would be difficult to establish as all activities would want to qualify for "green space status" and the request for flexibility could easily lead to a made-to-measure rather than to a transparent code.

This umbrella approach would give countries maximum leeway and create a more enabling environment for international negotiations as countries would be more likely to commit. With well over two-thirds of CO_2 emissions coming from non-tradable activities, and hence not subject to direct carbon leakage, countries with large energy subsidies would first enact energy legislation. For example, the US could first pass an energy bill which would raise the price of carbon.[38]

Under the umbrella of a broad multilateral agreement, which would set the basic rules like MFN and National Treatment (NT) under the GATT, much progress could still take place either in a small group, perhaps a G2 or G3, or even unilaterally (G1) as it has so far in many instances. This could be a much easier route than a Treaty at least for a country like the US. [39] As mentioned above, unilateral reduction in tariffs was the way most progress was made in the early rounds of trade negotiations. Of course, unilateral action is certainly easier to envisage in the case of tariff reductions where most gains are internalized than under GHG emissions where all gains are equally shared so that the need for collective action is much greater. Under this simpler architecture, in the initial steps forward, the UN process, which requires unanimity, would be by-passed. Using the words of Antholis, the new climate architecture would "gear up domestic steps that nations are willing to take".

[38] Following the demise of the Kerry-Lieberman propose bill, a new bipartisan bill (CLEAR (s.2877)) has been proposed by Cantwell and Collins in which no offsets would be allowed, all permits would be auctioned and revenues from the tax would be distributed to US residents. This unilateral approach would certainly put the US in a better position to enter multilateral negotiations and may get support if American households believe that the political-economy process will return to them a fair share of the revenues.

[39] Such agreements would require a simple majority in the Congresses rather than needing the super-majority at the US Senate for a Treaty.

A Polycentric Approach Drawing on the extensive experience of the provision of national and environmental public goods, Ostrom (2009) argues that, without denying the global nature of the problem, much progress on climate change can be achieved by actions at multiple scales (the household, the region, the country). Ostrom argues that this approach is precious in building the trust that is necessary to achieve the collective action that is still so elusive for climate change. In fact, currently all progress is taking place at the local and national levels rather than at the multilateral level.[40] While this decentralized approach has the advantage of building confidence, the very different approaches across countries and states will require later on much effort at the national level to conform those measures with any future rules in the multilateral trading system. But the multilateral trading system has withstood several shocks successfully including the rise of regionalism. So, one must hope that the confidence built by decentralized measures will pay off and will help build the needed commitment to achieve a binding General Agreement to Reduce Emissions.

[40] Wheeler and Shome (2010) estimate that India which is seriously considering a goal of 15 percent of renewable energy in its power mix by 2020 could effect the shift from coal-fired plants to renewables at a cost of 50$ billion. They note that India is contemplating this option despite the absence of any meaningful international pressure to cut emissions and no guarantees of compensatory financing, and argue that the government has concluded that it should promote clean power anyway, in order to develop an internationally competitive supplier industry, to bolster energy independence, and to help limit climate change because it will pose dire threats to India itself.

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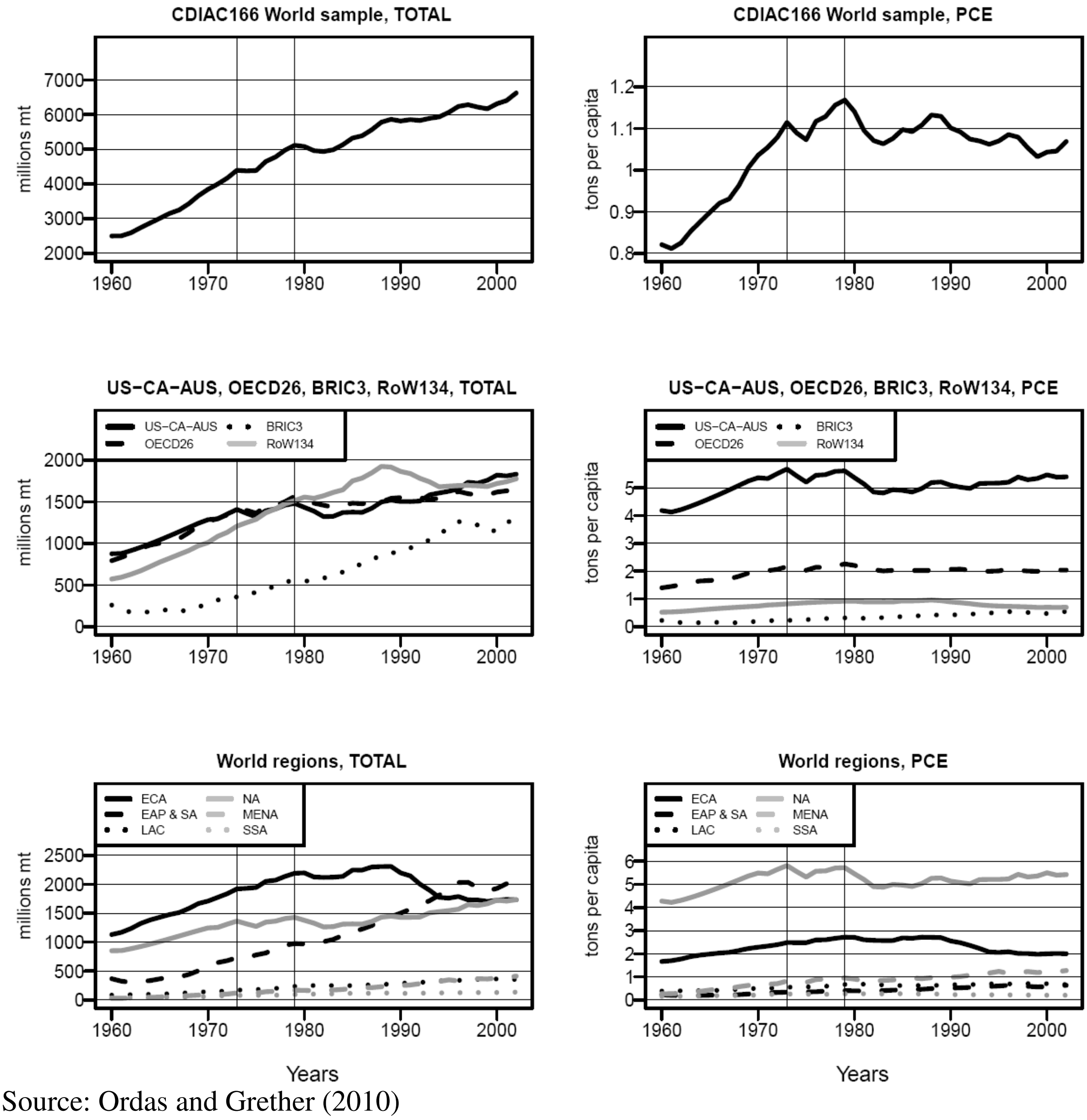
Tables, Figures
Trade and Climate Change: The Challenges Ahead

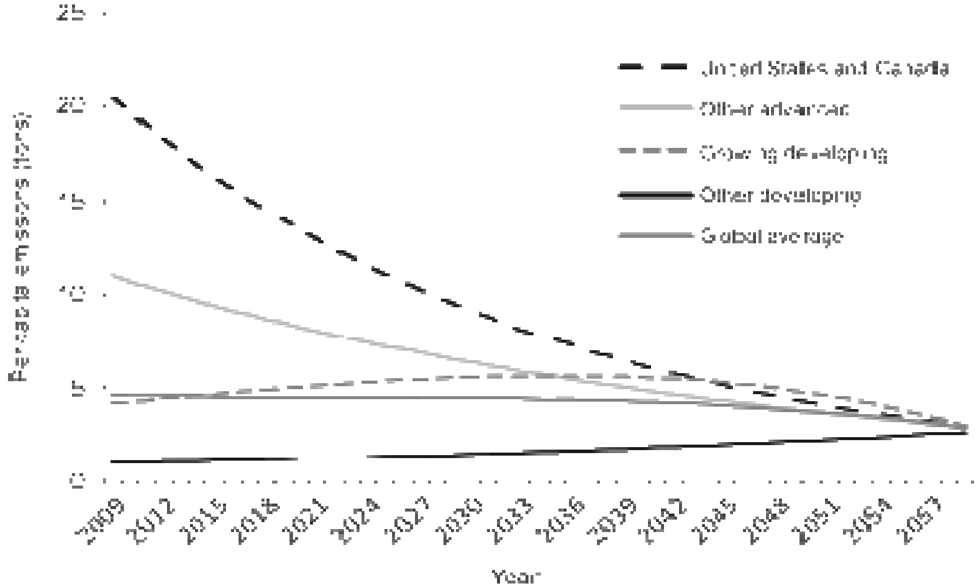
Figure 1: Total and Per capita carbon emissions: 1960-2002



Source: Ordas and Grether (2010)

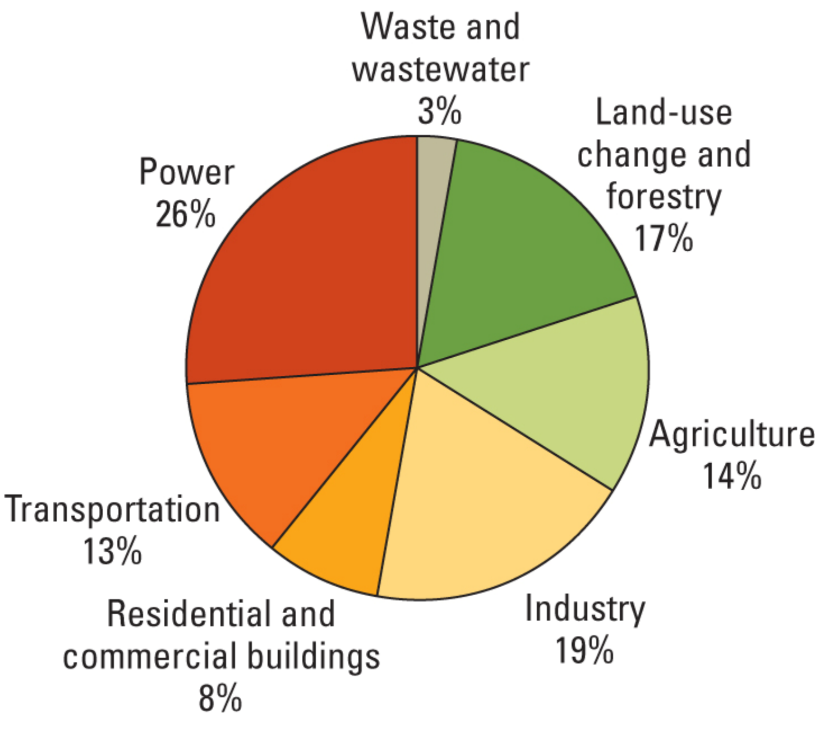
Notes: BRIC3 (Brasil + China + India), USA/CA/AUS (USA, Canada, Australia), OECD26 is the OECD without USA-CA-AUS, RoW134 includes the remaining countries, hence a total of 3 + 3 + 26 + 134 = 166 countries; Geographic Groups: ECA: Europe and Central Asia, EAP: East Asia, Pacific, SA: South Asia, MENA: Middle East and North Africa, LAC: Latin America and Carribean, SSA: Sub Saharan Africa; Initial data is from Carbon Dioxide Information Analsysis Center (CDIAC) and reflects anthropogenic emissions from fossil fuel consumption, cement manufacturing and gas flaring, ignoring fuels supplied to ships and crafts. To convert carbon emissions into CO2 emissions, apply a multiplicative factor of 3.67.

Figure 2: Per capita emissions on path to safe target



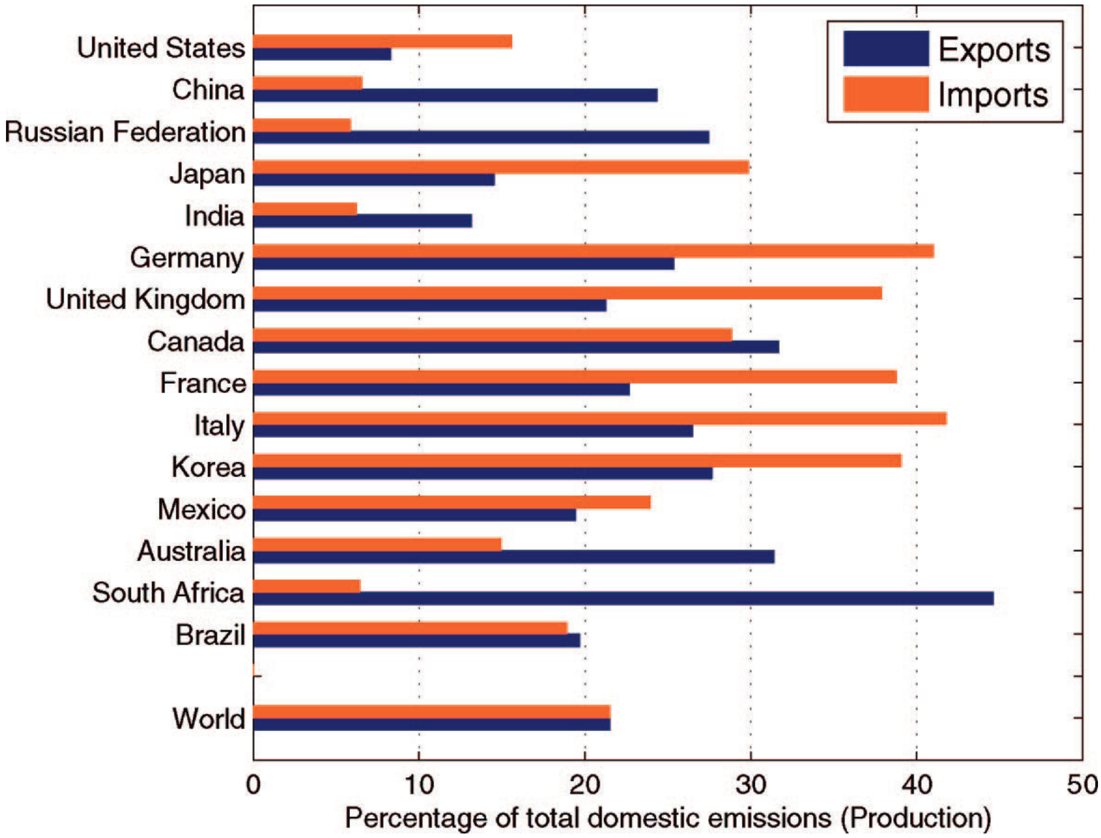
Source: Spence (2009, figure 2)

Figure 3: Major Sources of GHG Emissions



Source: IPCC 2007a, figure 2.1.
Note: Share of anthropogenic (human-caused) greenhouse gas emissions in 2004 in CO_2e. Greenhouse gas emissions include carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), and high-global-warming-potential gases (F-gases). All are expressed in terms of CO2 equivalent (CO2e)—the quantity of CO2 that would cause the same amount of warming. Emissions associated with land use and land-use change, such as agricultural fertilizers, livestock, deforestation, and burning, account for about 30 percent of total greenhouse gas emissions. And uptakes of carbon into forests and other vegetation and soils constitute an important carbon sink, so improved land-use management is essential in efforts to reduce greenhouse gases in the atmosphere.

Figure 4: Embodied CO2 emissions in imports and exports



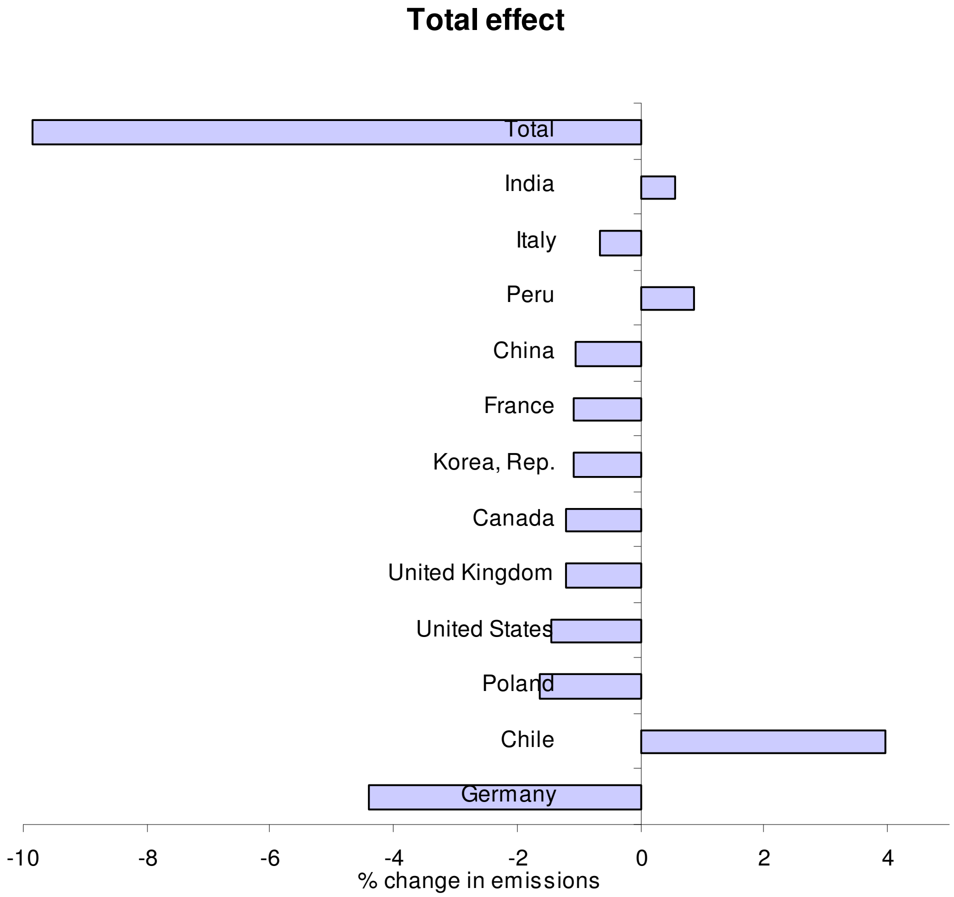
Source: Peters and Hertwich (2008)
Notes: Based on GTAP v6 data for 87 countries in 2001 using domestic IO data for bilateral trade flows.

Table 1: Comparison of CO2 and SO2 emissions

Characteristics	**Sulfur dioxide**	**Carbon dioxide**
% from transport	7%	21%
% from industry	30%	21%
% from energy transformation	51%	42%
Atmospheric life	1-10 days	50-200 years
Resultant impact		
Local	Yes	no
Transboundary	Yes	no*
Global	No	yes

Source: Cole and Elliott (2003)
Notes: * the dispersion of CO2 would never be restricted to a certain region or group of countries, Sources of SO2 emissions based on a sample of OECD countries for 1996 and sources of CO2 emissions are based on a world sample for 1997.

Figure 5: SO2 emission growth decomposition by country and sector
5a) Contribution of each country to total effect (ranked by decreasing absolute total effect)



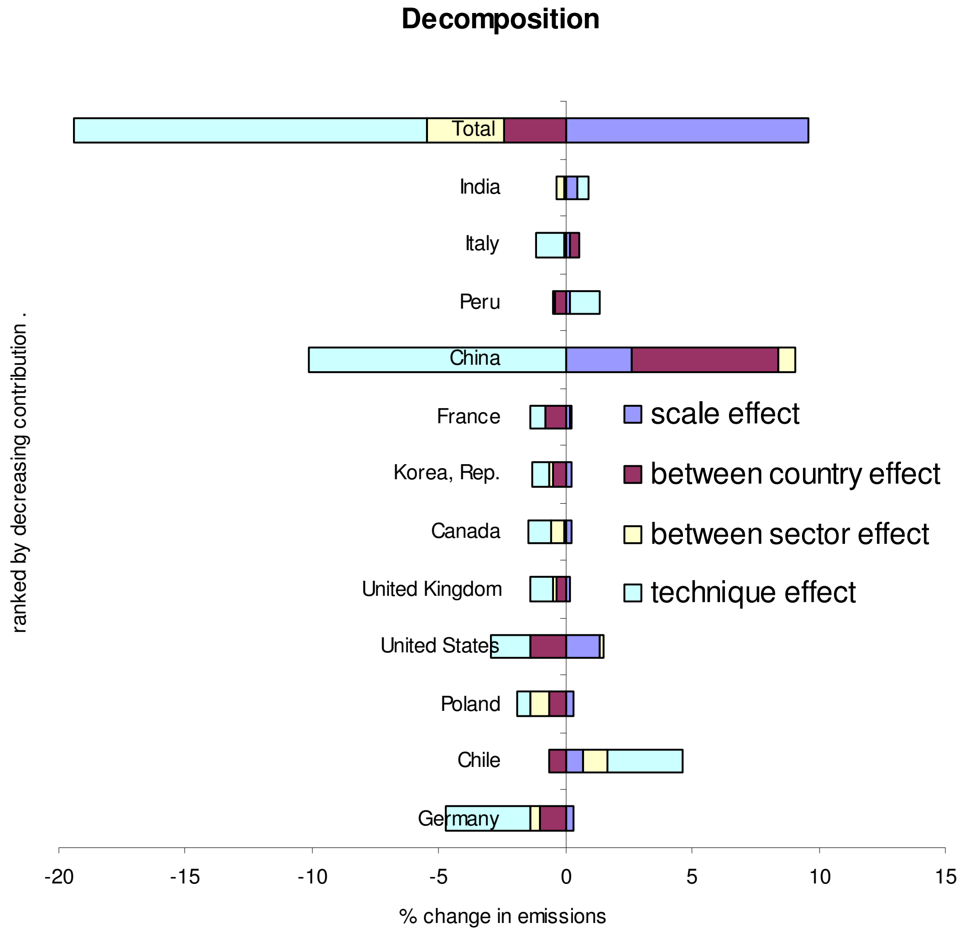
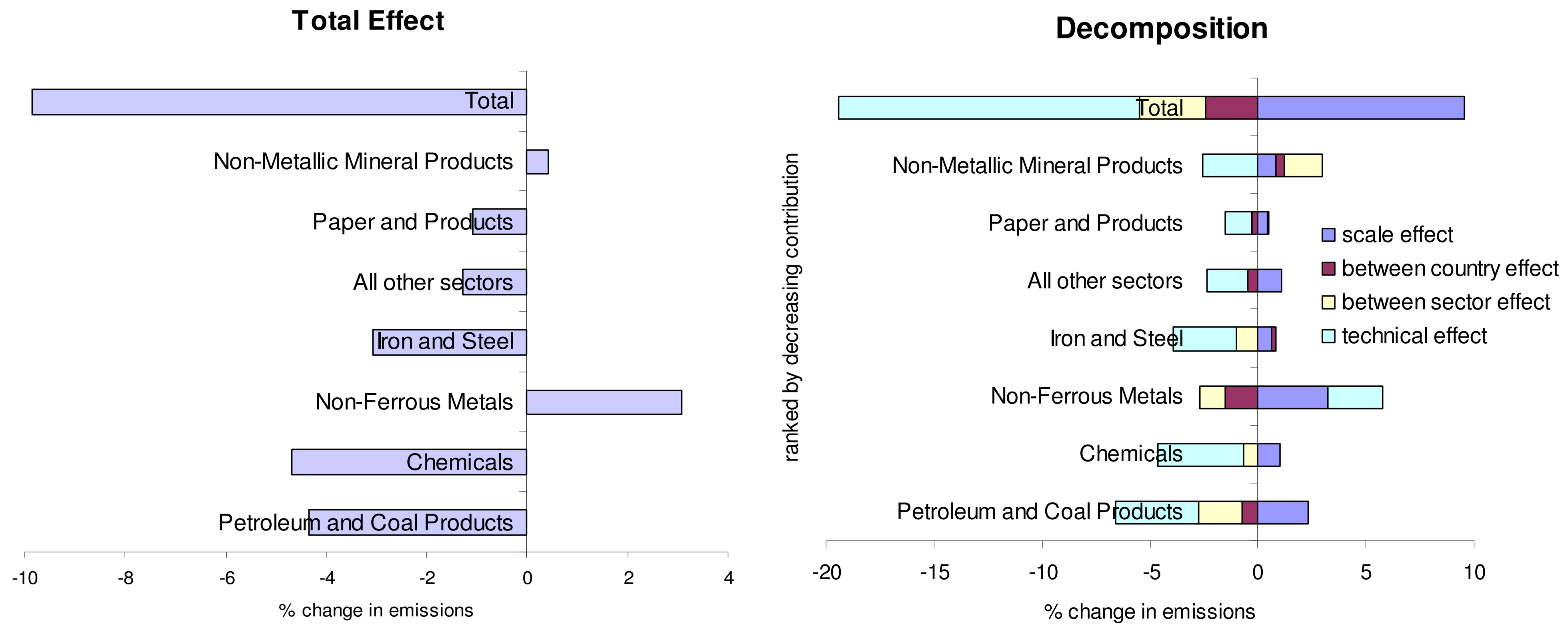


Figure 5: SO2 emission growth decomposition by country and sector (ctnd)

5b) Contribution of each sector to total effect (ranked by decreasing absolute total effect)



Source: Grether et al (2010)

Notes: Based on data for 62 countries, 7 sectors and over the period 1990-2000. SO2 emissions from Grether et al (2009)

Figure 6: In a Nutshell: Justifying Border Measures on Imports under WTO law

Party A complains about discrimination of its imports in Party B.

Coverage of Party B's BTA measures by GATT Articles II,III ?

Yes

Consistency with GATT articles II, III?
II: BTA must be a charge imposed on imported products that is equivalent to the tax imposed on "like" domestic product.
III: BTA is allowed in respect of taxes "applied directly or indirectly, to like domestic products".

Yes

No discrimination with respect to non-violation of articles II and III in this respect.

No

Exception is possible under: GATT article XX.
Chapeau: has not to be an "unjustifiable or arbitrary" discrimination.
Paragraph (g): "relating to the conservation of exhaustible natural resources …".

Yes

The measure is justified under GATT XX.

No

The measure is not justified under GATT XX. Party B must change its measure.

No

The measure is thus not under the coverage of the GATT.

Annex
Leakage and Competitiveness Estimates

Three issues related to trade and climate have been the subject of large empirical literature based on simulation modelling; (i) the effects of a carbon tax on emissions and on carbon leakage since not all countries will put a cap on emissions or apply a carbon tax; (ii) the effects on competitiveness, measured by the fall in domestic production resulting from the increased production costs related to abatement; (iii) the functioning of the EU's Emission Trading System (ETS) since it is likely that any global agreement will include a global Carbon Credit Trading System (CCTS) along the lines of improved CDM and ETS systems.

Table A1 summarizes the results from the literature. The first two columns describe the modeling approach and aggregation (i.e. which sectors are under investigation). The middle column describes the policy scenario, often a tax of 20-40$ per tCO2 and the last two columns the main results, often concentration on leakage estimates where the leakage ratio (LR) is defined as the ratio of the increase in emissions outside the region installing the climate policy over the decrease in emissions in the region installing the climate policy. All studies listed are ex-ante studies, (see the main text for ex-post studies) and they are grouped into partial equilibrium models concentrating on the heavy CO2 emitters, followed by the general equilibrium estimates usually from multi-region (MR-GE) models.

When the ETS was set up, the EU's energy-intensive sector complained that the increased production costs from CO2 abatement could not be passed on as higher prices because of competition from imports. For example, aluminium is a highly homogenous traded good which cannot pass on increased costs to customers. This gave rise to strong opposition to auctioning (and to misunderstandings about the causes of electricity price increases when the ETS system was introduced). [41]Table A2 gives the estimated cost increase (%) resulting from a market price of allowances of 20 euros/tCO2. The last column gives the estimated "offset" i.e. the percentage of the price increase that can be passed on to customers. For example, costs of producing cement would go up by 36.5%, but only 0-5.5% of that increase could be passed on (i.e. at least an increase in costs relative to price of 31%). Pass-through estimates are also used in some of the simulation results reports in table A1. No estimates are given for electricity since it is a non-traded good. According to these estimates, the potential for pass-through is rather low.

[41] Ellerman and Joskow (2008) evaluate the ETS from an American perspective concluding that the trading systems at the national and international levels have been implemented differently with the decentralized aspects of the ETS being a reflection of the multinational character of the EU.

Appendix Table A1: Overview over competitiveness and leakage estimates

Authors	Model	Aggregation	Policy Scenarios	Main result	Details
			Partial equilibrium		
Demailly-Quiron (2008) [a]	static PE – 4 sectors (CASE), EU27-RoW simulation for 2015	cement (0.8)[b], steel (0.88), ELE (0.37) aluminum (3.5), 100% pass-trough	Assess proposals to reform EU ETS (15% cut in emissions): GF, OB, AU-BA, OB for steel and cement AU for ELE	Negligible loss for Cement and electricity, larger for steel (low emission intensity) and aluminum (high trade elasticity)	Under AU or GF: LR= 30% (aluminium) LR= 20% (cement) LR= 45% (steel) overall LR=8% (GF and AU)[c] overall LR=-2% (AU-BA)[d]
Monjon-Quirion (2009)	static PE- 4 sectors (CASE II model, evolution of CASE), EU, simulation for 2016	cement, steel, ELE, aluminum	Assume 15% cut in emissions w.r.t. 2005, no other country takes action. 8 policy scenarios to tackle leakage and compare with AU	Most efficient way to tackle leakage: AU-BA, other efficient combination: AU in electricity and OB in exposed industry	LR=10% (AU) with steel 39%, aluminium 21%, cement 20%. LR= 2-3% (OB) With BA: leakage rate falls below 4% (BA more efficient than OB in this respect). Most BA policies entail negative leakage (= emissions in RoW decrease)
Fischer and Fox (2009)[e]	PE simulations for six energy-intensive sectors, US and Canada	ELE, OIL, CRP, NMM, PPP, I_S	BA-imp, BA-exp, BA-full, domestic production rebate, values derived from $50/tCO2 experiment in CGE	In comparison with rebate: all policies rise (reduce) domestic (foreign) production and emissions; policies cannot be ranked: depends on elasticities, size and emission rates; home rebate for most sectors most effective single policy	For US: LR= 64% (OIL), 60% (I_S), 39% (NMM), 20% (CRP), 11% (PPP), 8% (ELE); adjustment policies may even lead to increased leakage (mainly OIL) For Canada: generally higher LR (exception: OIL)
Gielen and	PE-perfect	all iron and steel	CO2 tax in Japan and	Significant loss of production,	LR=35% ($10/tCO2)

Authors	Model	Aggregation	Policy Scenarios	Main result	Details
Moriguchi (2002)	foresight LP-model (STEAP), Japan, 1965-2040, 11 regions	products (75 processes, 44 flows), with pass-through of 100%,	EU15; assumption: imports are perfect substitutes for domestic products, but there are trade barriers	strong interaction of technology and trade effects	LR=75% ($42/tCO2)
Ponssard and Walker (2008)	Oligopoly PE model with typical Western European country	cement, pass-through below 70%	Pure auctioning of allowances with CO2 price euro 20 and 50 / tCO2	Large increase in imports into costal region, as consequence for inland producers: reduced attractiveness of costal market and increased competition from costal producers and from non-EU imports	LR=70% ($20/tCO2) LR=73% ($50/tCO2) at $50/tCO2: import rate: 51% (coast), 23% (inland)
Demailly and Quirion (2008)	PE-model, EU15 and ROW	iron and steel, pass-through 75% for EU and 50% for non-EU	Effects of EU ETS, CO2 price: from 0 to 50 euros/ton with Gamma proba distribution and mean of 20 and a variance of 40 euros	Production losses are weak, even if 50% of allowances are auctioned, EBITAD loss would be modest: 3%	LR=5% (sensitivity interval: 0.5-25%)
Aldy and Pizer (2009)	Simulation based on regression analysis, 1986-1994, US	more than 400 manufacturing industries	US imposes price of $15/ton in 2012	Policy has relatively small effect for manufacturing as a whole, i.e. broad approaches to address competitiveness are inefficient. Better: targeting narrow set among energy-intensive industries.	Predicted impact on average manufacturing: -1.3% (production), -0.6% (consumption), -0.7% (competitiveness,) and -0.2% (employment)
			General Equilibrium		
Babiker	MR-GE,	5 energy goods	Kyoto targets under	Allowing for homogeneous	LR>100% (IRT-HO)

Authors	Model	Aggregation	Policy Scenarios	Main result	Details
(2005)	based on GTAP and IEA data, 7 world regions	and two non-energy composites	different scenarios: CRT-AR, CRT-HO, IRT-AR, IRT-HO	goods leads to much higher leakage rates than assuming imperfect substitution	LR = 60% (CRT-HO) LR=25% (IRT-AR) LR= 20% (CRT-AR)
Matoo et. Al. (2009)	MR-GE (ENVISAGE model)	15 regions, 21 sectors	CO2 emission reduction of 17% relative to 2005 by high-income countries NBTA, BTAM, BTAD and BTADX	BTADX small effects; BTAD; exports of developing countries would fall by 8% (and China by 16%)	World change in emissions w.r.t. BAU: NBTA: -9%; BTAM: -11%; BTAD: -10%; BTADX: -10% Change in exports of manufacturing: NBTA: 1%; BTAM: -13%; BTAD: -4%; BTADX: -1%
Rutherford (2010)	static MR-GE vs. MR-IO (LCA)[f] based on GTAP 7.1	21 regions, 61 commodities	CO2 emission reduction of 20% by high-income countries	Same results for MR-IO with 8 and 59 sector models; but MR-IO can provide misleading results for effectiveness of BA measures	LR= 18% (without BTA) LR= 7% (with BTA)
Böhringer et al (2010)	MR-GE (as Böhringer and Rutherford) 16 regions	5 energy intensive, transport services and a composite sector	US and/or EU 20% CO2 emission cut w.r.t. 2004 with AU, OB, RB, TF or BA	Leakage mostly via changes in global energy prices (not possible to address with BA). Rebates and adjustments do have significant effect on energy-intensive industries.	LR = 15-20% (US) LR = app. 35% (EU) LR= app. 20% (EU and US) (only small differences among scenarios: highest LR: Auction, lowest LR: BA)
McKibbin	MR-GE	5 energy-	Construction of	BA would be small, would	LR=10% (EU)

Authors	Model	Aggregation	Policy Scenarios	Main result	Details
and Wilcoxen (2009)[g]	(G-cubed: dynamic stochastic model), 10 regions	intensive sectors and 7 other sectors	hypothetical carbon tax beginning at $20 per metric ton, rising by $0.5 per year to $40, EU or US adopt tax or tax and BA	reduce leakage modestly and would do little to protect import-competing industries	LR=3-4% (US)
Ho et al (2008)	MR-GE (and PE for short run), GTAP v6	3 regions (USA, Annex1 and RoW), 21 sectors	Unilateral economy-wide CO_2 pricing ($10 per ton CO_2) of the US	Short run: output reductions are relatively large in key industries (petroleum refining, chemicals and plastics, primary metals and non-metallic minerals) long run: firms adjust inputs and adopt new technologies, leading to smaller output changes	long run: LR=25% overall, LR>40% for chemicals, non-metallic minerals and primary metals
Burniaux-Martins (2000)	MR-GE (GREEN model, recursive dynamic)	12 regions, 8 sectors and 7 energy backstops	Implementation of Kyoto protocol	Supply-elasticity of coal and shape of production function matter for LR, differentiation of manufactured goods and capital mobility less determinant	Elastic supply of coal: LR=5% (without permit trading) LR=2% (with permit trading) Inelastic supply of coal without permit trading: LR= 13% (with low degree of product substitution in coal market) LR= 23% (with high degree of substitution)
Peterson and Schleich	MR-GE, includes domestic	17 sectors (including coal, oil, gas and	implementing Kyoto with and without BA (EU15: -6.9%, rest EU: -33%,	for most energy-intensive sectors in EU15, BA will neutralize increased import	Low energy substitution: LR=25% High energy substitution:

Authors	Model	Aggregation	Policy Scenarios	Main result	Details
(2007)	trade and transport margins, 11 regions, emission trading	energy-intensive manufacturing sectors)	Japan: -12.7%, rest of Annex B: -25.1% with respect to 2005) allowing for credit banking for rest of EU	competition and more than neutralize the loss in export sales	LR=28% (none or half banking), 38%(all banking) With BA: low energy substitution: LR= 22% high energy substitution: LR= 26%

Footnotes:

a) Electricity (non-traded) +Steel, cement, Aluminum (traded sectors)- Sectors cover 75% of emissions under the ETS

b) (tCO_2 per unit—ton or MWH for electricity)

c) the negative Leakage rate is due to the fall in consumption following the increase in price.

d) LCA (life cycle analysis is a method to compute the carbon footprint of a production taking into account all inputs and in some cases the transport and other transaction costs prior to final consumption) computes the direct+ indirect carbon footprint (i.e. MR-IO) under the assumption of no substitution in response to a carbon tax.

e) Model is ignoring cross-price, income and ToT effects.

f) Model includes forward looking expectations.

Abbreviations:

AR	Armington assumption of differentiated goods by country of origin
BA	border adjustment
BTAD	as BTAM but based on carbon content of domestic production
BTAD	tax on imports based on carbon content --direct+ indirect--of domestic production
BTADX	as BTAD but they also apply rebates on all merchandise exports
BTADX	same as BTAD but exporters do not pay tax on CO2
BTAM	Industrial countries reduce by 17% and impose tariffs on all merchandise imports based on carbon content of imports
CRP	chemicals
CRT	constant returns to scale
EBITDA	earnings before interest, taxes, debt and amortization
ELE	electricity
HO	Heckscher-Ohlin assumption for trade (i.e. homogenous goods)
I_S	iron and steel
IRT	increasing returns to scale
LP	linear programing
LR	leakage rate: (increase in emissions outside restricted region) / (decrease in emissions in restricted region)
MR-GE	multiregional general equilibrium model
MR-IO	multi-regional input-output model
NBTA	Industrial countries reduce by 17% and take no trade policy action (no border tax adjustment)
NMM	nonmetallic minerals
OB	output based allocation
OIL	refined petroleum products
PE	partial equilibrium-based estimate usually from a sector-level simulation model with trade
PPP	pulp, paper and print
RoW	rest of the world
TF	tariff
ToT	terms of trade

Appendix Table A2: Estimated cost increase (%) with market price of 20 euros/tCO2

	Direct effect (allowances)	Indirect effect (electricity)	Total effect	Estimated Price offset (%)	
Aluminium					
Primary production	0.0	11.4	11.4		0.0
Secondary production	0.0	0.5	0.5		0.0
Cement					
Dry process	34.4	2.1	36.5	0 -	5.5
Pulp & paper					
Chemical pulp for market	0.5	0.5	1.0		0.5
Paper from chemical pulp	1.1	1.0	2.1	0 -	0.4
Chemical P&P	1.4	1.0	2.4	0 -	0.5
Mechanical P&P	1.4	4.1	5.5	0 -	1.1
Thermo-mechanical P&P	1.4	6.1	7.5	0 -	1.5
Recovered fibre P&P	1.6	1.8	3.4	0 -	0.7
Refining					
Average process	19.0	1.5	20.5	5 -	15
Steel					
BOF (mainly flat)	15.3	2.0	17.3		1.1
EAF (mainly long)	0.4	2.5	2.9		1.9

Source: EU ETS REVIEW, Report on International Competitiveness, December 2006.

Source: Nordström (2009), p. 25.

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Contact
www.ferdi.fr
contact@ferdi.fr
+33 (0)4 73 17 75 30