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Trade, climate change and the political game theory of border carbon adjustments

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ABSTRACT

The lack of real progress at the Durban climate change conference in 2011—postponing effective action until at least 2020—has many causes, one of which is the failure to address trade issues and in particular carbon leakage. This paper advances two arguments. First, it argues that the conventional view of Border Carbon Adjustments (BCAs) as a "dirty" trade barrier should be turned on its head. Rather, the *absence* of a carbon price comprises an implicit subsidy to dirtier production in non-regulated markets. Second, BCAs could act as a game-changer when climate policy negotiations move at a glacial pace, if at all. Materially stronger progress could be achieved indirectly from the threat of unilateral trade policies. The paper shows how this could come about, using a simple political game theory model. The appropriate game form is one in which parties move unilaterally and sequentially, given the failure to agree on a common course of action, and are fully aware of the impacts of their actions. The paper shows that properly crafted BCAs could help reduce trade distortions, limit the competiveness effects, and help build a broader coalition of interests for more global actions.

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1. Introduction

The lack of progress on an international climate change agreement shows no sign of being resolved any time soon. The Durban Conference of the Parties in December 2011 kept the Kyoto framework on life support, but only on the basis of an agreement to try to reach an agreement by 2015 about emissions caps after 2020. Amongst the main polluters, the USA is not doing much at the federal level. China is making significant investments in renewable energy, but is still rapidly adding more coal-fired power generation. Global emissions have not been dented since 1990, and globally coal has continued to increase both in relative share and in absolute amount. The only event that has made any substantial difference to global emissions is the economic crisis and the associated reduction in economic growth, but even this has had only a limited effect. Otherwise, 20 years of international actions (notably focused on the Kyoto Protocol) have produced no significant mitigation.

Against this background, the various national and regional carbon policies have had the consequence of distorting trade. The result of patchwork efforts to address climate change has been the emergence of a two-speed carbon[3] world – some (mainly Europe and soon Australia and perhaps China) with a variety of carbon prices, but most without. This creates clear and unambiguous price distortions to trade, and it is reinforced by multiple differences in energy taxes, which are high in Europe, lower in the US and negative (in the form of fossil fuel subsidies) in the Middle East, Russia and elsewhere.

These trade distortions have themselves had a negative feedback on climate policy. In Europe and Australia, attempts to mitigate trade and competitiveness concerns have created further distortions and rent-seeking activity. The policy of choice in the European Emissions Trading Scheme (EUETS) and the Australian Carbon Price Mechanism (ACPM) has been to address trade concerns by giving permits to "emissions-intensive trade-exposed" industries for free. This constitutes an exemption (or implicit subsidy) for such sectors. This policy opened the way for large-scale lobbying and generated major inefficiencies. The problems that arose did not passed unnoticed, however. Recognising that allocating permits for free has several serious economic drawbacks, the proportion of permits being auctioned in the EUETS has since been increased and continues to increase as time passes.[4]

In contrast, the US has been clear that it will not accept emissions caps until and unless trade concerns are resolved with border carbon adjustments. The requirement for importers to purchase emission allowances was included in the now defunct Waxman-Markey Climate Bill, and is likely to be a core part of any US action on climate change. Adjustments to trade may work the other way too: in 2010 the US began investigating claims by the US steel workers union that China had violated WTO rules through the provision of billions of subsidies to

[3] Throughout the paper we use "carbon" as a shorthand for "greenhouse gases" unless otherwise stated.
[4] See Hepburn et al. (2006) and Hepburn, Quah and Ritz (2008).

clean technology. This type of squabbling will probably escalate in the coming years.

This paper argues that a better response to trade distortions is the adoption of so-called Border Carbon Adjustments (BCAs). These include three types of measures: (i) border taxes (as tariffs on imports and, less commonly, rebates on exports); (ii) mandatory emissions allowance purchase by importers; and (iii) embedded carbon product standards (Wooders et al., 2009). In every case, the objective is to extend a domestic carbon pricing scheme to traded goods. BCAs more generally are gradually working their way onto the EU agenda. The incorporation of aviation into the EUETS has served as a *de facto* BCA, as the entire emissions from any flight that arrives or departs the EU are captured, irrespective of whether the emissions occur over other countries' airspace. This has led to vociferous complaints by India, China, America and around 20 other countries. A (failed) pre-emptive attempt by India to table a resolution banning BCAs at the Durban conference signals the battles that may be to come.

This paper advances two specific arguments in favour of BCAs. First, it argues that the conventional view of BCAs as a "murky" trade barrier[5] should be turned on its head. Rather, the *absence* of a carbon price effectively comprises an implicit subsidy to dirtier production in non-regulated markets. Despite the conventional wisdom, it is the implicit subsidy (which is a market imperfection), rather than a BCA (the correction of a market failure) that should be regarded as the distortion. The fact that BCAs may potentially reduce trade does not mean that they create a distortion — incorrect factors prices create "too much trade" and "too much pollution", reducing welfare.[6]

Second, in addition to removing a market distortion, BCAs could act as game changer in a situation in which climate policy negotiations are barely moving. An effective climate 'deal' will depend on the inclusion of trade measures (e.g. Barrett 2011). Such a new climate framework could arise indirectly from the threat of unilateral trade policies. We show how this could come about, using a simple political game theory model, where the sub-game perfect Nash equilibrium (SPNE) is a world with increasing BCAs. We do not rule out in principle the possibility of trade disputes and retaliation over climate actions. Rather, trade policy considerations are an essential part of our political economy argument. In addition, trade considerations could also lead us towards stronger global environmental policies that do not rely upon floundering international negotiations. Properly crafted BCAs could help reduce trade distortions, limit

[5] See Evenett and Whalley (2009) for an overview of "green protectionism", one form of "murky protectionism".

[6] BCAs correct a distortion (by pricing the externality in imports), but because they reduce trade it might be thought that they create another distortion. It might therefore be argued that countries should price carbon domestically and provide a subsidy to exporters instead of a BCA. This would fail to price emissions in both imports and exports (creating a distortion), but there would be no reduction in trade. However, trade itself is not the objective; increased welfare is the objective. Trade can only be guaranteed to improve welfare when prices reflect the correct social costs. Incorrect prices can lead to sub-optimally high or low levels of trade in goods (or bads), which can reduce welfare.

the competiveness effects, and help build a broader coalition of interests supporting more global actions.

Use of game theory is not new in the context of trade policy and multilateral environmental agreements. This paper's novelty consists in the application of game theory to the issue of BCAs. Two assumptions are made. First, that parties involved move sequentially, that is, BCAs are unilateral actions that can be followed by other unilateral (trade or climate policy) actions. In other words, parties do not agree simultaneously on a course of action (as in a multilateral environmental agreement). In fact, the failure to agree on a global course of action on climate change, is the starting point of the paper. Second, it is assumed that each party knows the extent to which their actions impose costs on other parties. These two assumptions justify the use of a sequential move, or dynamic, game of full information. The relevant equilibrium concept is the one of sub-game perfection.

The paper is structured as follows. Section 2 summarises the interaction between trade theory and environmental economic theory. Section 3 summarises the different carbon prices around the world. Section 4 reviews the relevant empirical evidence to determine whether implicit carbon subsidies are distorting patterns of production, consumption and pollution, and the likely impact of BCAs on these variables. Section 5 explores the relationship between the production and consumption of greenhouse gas emissions. This motivates the core analysis of the paper, in section 6, from an economic, legal, political and practical perspective. Properly implemented BCAs would be equivalent to pricing emissions on a consumption basis, rather than a production basis, and this is the essence of our proposal. Section 7 concludes.

2. Trade and Environmental Economic Theory

Trade theory supports our first argument that it is the absence of carbon prices that acts as a distortion, not the other way around. According to the simple trade theory of Ricardo and others, two trading partners will both gain from trade if, in autarky, they have different relative costs of producing the same goods. Differences in costs can include, in utility or other terms, negative externalities—such as pollution—involved in the production of the good. Countries who are more tolerant of pollution may thus gain by specialising in the production of 'dirty' goods.

On this simple view, any measure that aims at restricting trade *based on how a good is produced* (e.g. using fossil fuels vs. renewable energy) is viewed as contrary to basic principles of economic efficiency. However, this is based on the assumption that the inputs are properly priced. Climate change involves a global negative externality and the failure to internalise the negative (global) impacts of carbon emissions represent a *de facto* subsidy to the costs of production.[7]

[7] As Stiglitz (2006) argued: "not paying the cost of damage to the environment is a subsidy, just as not paying the full costs of workers would be… But American firms are being subsidised—and massively so". He advances the logical solution: "other countries should prohibit the importation

The mainstream economics literature shows that the failure to put a price on global emissions is inefficient. Free trade can reduce welfare when there is a global externality that has not been internalised (Chichilnisky, 1994; Copeland and Taylor, 1995). Chichilnisky (1994) shows that trade between a region with well-defined property rights and a region with ill-defined property rights increases global pollution and reduces welfare because the former over-consumes goods, produced with dirty technologies. Even assuming well-defined property rights over resources in all trading regions, more trade can still imply more pollution and lower welfare. Copeland and Taylor (1995) examine a model in which trade is driven by the differences in human capital between countries. Countries endogenously choose in which industries to specialise and in so doing implicitly determine their pollution intensity. They show that a movement from autarky to free trade raises world pollution and, as a result, developed countries over-consume carbon intensive products. The literature on trade and the global environment shows that in the presence of global externalities, increasing integration of markets worldwide may be a major driver of pollution.

In relatively simple models, the first-best solution is free trade, coupled with a common global carbon price, which would achieve the maximum welfare with the external costs of carbon emissions internalised. This might be through a tax, in the spirit of Pigou (1920), or through the creation and enforcement of property rights over the atmosphere, a precondition for Coase's (1960) efficient solution to take place. However, the latter requires a self-enforcing global agreement that has so far failed to materialise, because there is no international court to enforce property rights over the atmosphere. Rather, any outcome on the allocation of rights to use the atmosphere will be necessarily determined by political negotiation.

In our second-best world, carbon prices are far from uniform, and trade policy must inevitably play a crucial role in delivering tolerable outcomes (e.g. Whalley, 2011). Unilateral carbon pricing schemes, without associated BCAs, may result in far from even second-best outcomes if they simply shift production to less regulated markets, a phenomenon known as 'carbon leakage'. At the heart of the Kyoto Protocol's failure to address climate change is the fact that fast growing developing countries such as China and India do not have binding quantitative emissions targets. This is one of the reasons for the US refusal to ratify the Kyoto Protocol. What makes matters worse is that these countries are the source of the bulk of the emissions growth, based primarily on an increasing coal burn.

An ambitious, legally binding deal may or may not be reached in 2015. Past experience provides a brake on optimism. If it is not reached, unilateral carbon measures, coupled with BCAs, are about the only real option available to address climate change. Even if such a deal were to be reached, BCAs are potentially a critical supporting part of the policy package, because they (i) put a price on the carbon content of imports; and/or (ii) rebate the carbon price paid domestically

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of American goods produced using energy intensive technologies, or, at the very least, impose a high tax on them, to offset the subsidy that those goods currently are receiving."

by exporters. BCAs work in association with a domestic carbon pricing scheme, so that the playing field is level for domestic and international producers (Cosbey, 2008).

To date, the main reasons advanced in support of BCAs have been competitiveness concerns and carbon leakage[8]. Each refers to different perspectives on the same phenomenon.

There are further, less well-appreciated reasons in favour of BCAs. Regardless of the presence of leakage, BCAs correct the imbalance in GHG emissions created by free trade in the presence of differential carbon pricing. BCAs associated with a domestic carbon price are equivalent to putting a price on *consumption* of carbon rather than *production*. The virtue of a price applied to consumption is that a consumption-based price remains effective even as the long-term process of de-industrialisation in developed countries continues. As an extreme case, suppose that developed countries achieve 100% emission reductions such that their production involves no emissions. A carbon price applied to producers would then have no effect whatsoever. The only way to further reduce the global externality would be to charge a price on consumption of carbon.

The use of trade measures in combination with international environmental agreements is not new. There are examples in which trade measures have been mutually agreed as part of multilateral negotiations on an environmental agreement. Some have had remarkable success. In the most notable cases, trade measures have not only helped the working of the environmental agreement, but they have done no harm to the trade system (Barrett, 2011). For instance, a key provision of the Montreal Protocol, adopted in 1987, provides for a ban on trade in controlled substances and products containing them. According to Barrett (2010), the most important motive for inclusion of such restrictions was to enforce participation in the agreement, rather than punishment. Approved in 1911, the Fur Seal Treaty successfully exploited the fact that all sealskins were processed in London: imposing a ban on imports of seal skins coming from non-parties was remarkably effective.

Things are different with climate change. A ban on trade in products containing carbon would be obviously impossible to adopt, whereas BCAs are possible. Two elements are important for success: their credibility, and size of impact. BCA credibility requires that countries adopting the BCAs have an incentive to retain them, i.e. are not subject to any credible threat of retaliation.

The next step is to note the extent of heterogeneous carbon prices around the world, before turning to the empirical evidence on the likely impact of BCAs.

3. Carbon prices around the world

[8] Carbon leakage may be defined as the ratio of the increase in emissions from a specific sector outside the country over the emission reductions in the country, as a result of a climate policy affecting that sector in the country (Reinaud, 2008)

Carbon pricing schemes, aimed at reducing emissions, come in a variety of forms, including cap-and-trade, carbon taxes, renewable energy and energy efficiency certificates. The most extensive carbon pricing scheme worldwide is the EUETS, which operates in 30 countries (the 27 EU member states plus Iceland, Liechtenstein and Norway). In 2013 the EUETS will enter its third phase in which at least 50% of the overall emission allowances are planned to be auctioned (compared to about 3% in the period 2008-2012). Notably, in 2012 the EUETS is to be expanded to cover aviation emissions which account for 3% of the EU's total GHG emissions and which are growing rapidly (World Bank, 2011). In 2012, 15% of aviation emission allowances are to be auctioned to European and foreign airline companies.[9] The share of auctioned allowances may change over the coming years.

Other developed countries are lagging behind. California's cap-and-trade scheme, due to start in 2012, is likely to be the largest scale North American effort on GHG emission reduction for the foreseeable future (World Bank, 2011). Under the scheme, annual emissions limits will be applied to utilities and large industrial plants (later on it will include fuel distributors) throughout the state of California. Emission allowances will be reduced by 2% every year until 2015 and by 3% every year between 2015 and 2020. In Australia, the Senate recently approved the Clean Energy Future Act that will force the country's 500 worst-polluting companies to pay a tax on their carbon emissions from 1 July 2012, with a trading scheme replacing the tax from 1 July 2015. New Zealand is undergoing a review of its NZ ETS. In Japan, the ETS under the Basic Act on Global Warming Countermeasures has faced strong opposition, particularly given the slow progress made in the international negotiations.

In developing countries, carbon pricing schemes are by and large absent or in their infancy. China released its 12th Five Year Plan of National Economic and Social Development in March 2011, setting carbon intensity reduction targets of 16% by 2015. On November 22, 2011, the government announced the approval of a pilot greenhouse gas emission rights trading scheme in seven areas (cities and provinces). India also has a voluntary target to reduce the amount of carbon dioxide released per unit of gross domestic product by 25% from 2005 levels by 2020. The coal tax approved in 2010 is a step in that direction. South Africa is contemplating the adoption of a carbon tax that would be instrumental in achieving the voluntary commitment to reduce GHG emissions by 34% below BAU trajectory by 2020 and by 42% below BAU by 2025.

Despite the initiatives mentioned above, energy subsidies (both to production and to consumption) still contribute to widen the gap in implicit carbon prices between the regions that implement them and other regions. IEA (2011) estimates that fossil-fuel consumption subsidies worldwide amounted to USD409 billion in 2010.[10]

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[9] See section 5 below for the trade dispute that this proposal has already caused.

[10] The IEA does not calculate production-side subsidies due to data limitations. The bulk of fossil fuel consumption subsidies go to oil (47%), followed by gas (22%) and coal (less than one percent).

In developing countries, subsidies to energy are particularly large. IEA (2011) estimates that, in 2010, fossil fuel consumption subsidies amounted to USD166 billion in the Middle East, USD39 billion in Russia, USD22 billion in India and USD21 billion in China[11]. Production subsidies, particularly in developing countries, are very difficult to estimate. For example, Koplow et al. (2010) indicates that producer subsidies to fossil fuels in China are pervasive, though difficult to quantify. The government (national, provincial and local) still owns key portions of the fossil-fuel supply chain, so aid to fossil fuel production comes in a wide array of tax breaks and widespread credit subsidies, in addition to concerted support (including financial) for developing fossil-fuel resources outside China. Coal is mostly consumed in the non-electricity industrial sectors, such as iron and steel, and cement. These commodities receive substantial subsidies.

In 2009, the G-20 agreed to the gradual phase out of fossil fuel subsidies. Progress to date has been mixed. In a global survey covering 37 countries where subsidies exist, at least 15 have taken steps to phase them out since the start of 2010. Without further reform, the cost of fossil fuel consumption subsidies is set to reach $660 billion in 2020, or 0.7% of global GDP (at market exchange rates) (IEA, 2011).

Thus there are not only differential carbon prices between countries, but also additional gaps between carbon prices and fossil fuel prices as a result of differential energy taxes and subsidies. At the international level carbon and energy taxation is at best described as a mess, but with corresponding scope for large efficiency gains from arbitrage and trade through global carbon price harmonisation. That is the prize.

4. An examination of the empirical evidence

These distortions to trade matter, and we now turn to the empirical evidence on the potential scale of these effects. Are developed countries consuming less carbon as a consequence of Kyoto? Is leakage occurring? If BCAs were to be applied, would they make much difference to trade patterns? These are empirical questions. This section reviews the recent literature to provide answers.

4.1 Consumption vs. production of carbon

As noted in section 2 above, a key insight from the trade and environment literature is that the gains from trade favour over-consumption of the environment by developed countries. There is a burgeoning literature that analyses the extent to which carbon is embodied international trade flows (e.g. Wiedmann, 2009). Studies are divided in two categories: (i) studies that analyse trade flows to and from individual countries, and (ii) studies that use input-

[11] By contrast, OECD (2011) estimates that consumption and production subsidies in the OECD have ranged between USD45 billion and USD75 billion per year in 2005-2010. Coal is the largest and most visible of production subsidies in the OECD (39% of total fossil fuel producer support in 2010).

output models to track flows of carbon between multiple trading partners. An advantage of multi-country studies is that they provide insight into the quantities of embodied emissions in final goods throughout the different stages of production.

Davis and Caldeira (2010), in a multi-country study, find that the US, Japan, the UK, Germany, France, and Italy are major net importers of embodied emissions. In terms of (gross) imports, the US is by far the largest recipient of emissions, which are primarily embodied in machinery, electronics, motor vehicles and parts, chemical, rubber, and plastic products. However the US also exports large amounts of emissions through transport services, machinery, electronics, chemical, rubber and plastic products. The balance of trade is very similar in EU countries and Japan. China is a major net exporter of embodied emissions, particularly through machinery, electronics and apparel. This pattern can be found in all major emerging economies. Atkinson et al. (2011) also show the main net exporters of embodied emissions (to which the authors refer as 'virtual carbon'), are China, Russia and other middle income countries, while the main net importers are the EU, USA and Japan. Peters and Hertwich (2008) reach similar conclusions.

Taking the UK as a case in point, Wiedmann et al. (2008) use a multi-region model to show that, over time, there has been a considerable increase in carbon consumption-based emissions and a widening gap between production and consumption-based emissions. Druckman et al. (2008) show that any achievement in reducing production-based emissions disappears when a consumption-based perspective is taken. Helm et al. (2007) reach a stronger conclusion: the UK's performance in reducing GHG emissions turns from moderately positive, if one focuses on production, to strongly negative once consumption of emissions are taken into account. They show that between 1990 and 2005 UK emissions on a consumption basis rose by 19%.

These studies highlight a major failure of Kyoto: its exclusive focus on production-based inventories and policies. This design feature means that Kyoto gives a seriously misleading metric of achievement. In the absence of progress, the pressure for unilateral action to tackle the climate change problem is bound to increase.

4.2 Differential carbon prices and leakage rates

The fact that the consumption and production of embodied emissions differ across countries and over time does not necessarily imply that differential carbon and energy prices (implicit and explicit) are responsible for these shifts. The process of deindustrialisation that has been occurring in developed countries, and especially Europe, in past decades, has been driven by shifts in comparative advantage largely unconnected with climate policy.

Nevertheless, as noted in section 3 above, substantial cross-country differences in carbon prices now exist, and rightly or wrongly, these prompt fears of leakage.

Carbon leakage occurs when there is an increase in carbon dioxide emissions in one country as a result of emissions reductions by a second country with a stricter climate policy. It is associated with one of, or a combination of, three phenomena: (i) the choice by multinational firms to reduce production at European facilities and to increase production outside the EU; (ii) the choice of firms to locate new facilities outside the EU; or (iii) the choice of firms to close plant entirely in the EU and open substitute plant in other jurisdictions.

Economic theory suggests that carbon leakage problems might be significant in certain sectors. Both conventional industrial organisation models (Ritz, 2009) and new geography models (Feddersen, 2011) indicate that although the overall cost impact of carbon pricing is very small in most sectors, it is significant enough in some sectors to prompt one or more of the three leakage phenomena described above. Leakage is therefore unlikely to just be a "marginal" phenomenon. At small differentials in the carbon price between the EU and the rest of the world, it is possible that effects are negligible even in very "exposed" sectors, but once a threshold price is reached, the industrial cluster might shift to a new equilibrium and could be lost *en masse* to another jurisdiction, driven by network externalities. Such a loss of production can be irreversible, such that even if carbon prices eventually equalise, the new equilibrium is stable enough that production would not return to the EU.

These legitimate concerns about leakage have an impact on domestic efforts to introduce, and then raise, the price on carbon. Leakage has been successfully employed as an argument by internationally traded sectors to claim special subsidies and other support measures. There are also concessions on energy taxes in a number of EU countries. These exemptions and subsidies create further inefficiencies within the EU, both because of the lost opportunity of reducing taxes elsewhere, and because some exemptions can blunt abatement incentives at the margin, create perverse dynamic incentives, and increase market concentration (Hepburn, Quah and Ritz, 2008).

How much carbon leakage is caused by carbon price differentials? Any empirical investigation of leakage has two components. First, a policy difference between countries must be identified. Second, a measure of the change in emissions (domestically and abroad) that is attributable to the implementation of the policy must be determined. The definition of 'abroad' is important. For instance, if the EU is regarded as domestic, 'abroad' includes both low-cost manufacturing in China, but also carbon-intensive energy providers in Belarus, Ukraine and other border countries to the EU in eastern and southern Europe.

The IPCC Fourth Assessment Report (Barker et al., 2007) reviewed a number of *ex-ante* studies estimating carbon leakage rates post-Kyoto, concluding that leakage rates "range from 5 to 20% as a result of a loss of price competitiveness, but they remain very uncertain" (Barker et al., 2007). The Fourth Assessment Report goes on to conclude that concrete mitigating actions, such as the EUETS, have not been found to trigger significant competitive losses in countries of the EU.

The carbon pricing scheme that has lent itself to most empirical research is the EUETS. Given the short time since its implementation, and given that many energy intensive sectors have been excluded from the first phase of EUETS, it is however very difficult to measure empirically if it has had any impact on leakage – though this has not inhibited many lobbies and vested interests on both sides of the political debate from making bold claims. Given these unfortunate short timeframes, *ex ante* studies using general equilibrium models may provide more insight than *ex post* models that use historical data.

Ex ante studies usually rely on data for a single year for calibration. In general, most findings suggest leakage rates of around 10% (Kuik and Gerlagh, 2003; Gerlagh and Kuik, 2007; Paltsev, 2001; Mattoo et al., 2009). For instance, Kuik and Gerlagh (2003) find a leakage rate of 11% arising from the EUETS, and find that that Kyoto targets are mostly achieved through factor substitution (away from fossil fuels) rather than through relocation. One study, however, estimated a leakage rate of over 100% in one of the scenarios it considered (Babiker, 2005) and under very specific assumptions[12].

Leakage rates would be expected to vary widely between sectors, and should be highest for energy intensive sectors. Paltsev (2001) suggests that the most significant sectors are the chemical industry, the iron and steel industry, and final demand. Studies reviewed by Reinaud (2008), find that a EUR 20 per ton of CO_2 price applied to the European Union (EU-27), leakage rates range between 0.5% to 25% in the iron and steel sector and between 40-70% in the cement sector, depending on how allowances are distributed among other parameters. McKinsey (2006) also note that the risk of leakage, particularly in the cement sector, is 'real' even with an emissions quota allocation method based on historic emissions.

Moving from *ex ante* to *ex post* studies, so far there is very scant evidence of leakage based on actual data. Ellerman et al. (2010) analyse changes in net imports of cement, iron and steel, refined oil and aluminium in the first period of the EUETS (2005-7). Unsurprisingly, given the nature of the first period and the exemptions, the study finds no evidence that the first trading period of the EUETS induced an increase in net imports. For cement, the study observes: that various trade barriers may protect domestic cement production, that current producers enjoy the possibility of passing through a large portion of the increase in carbon price, and that producers have been receiving generous emissions allowances. For oil refineries, the high profit margins in the previous few years have meant that carbon price has not been a major determinant of declining competitiveness. For aluminium, confounding factors include long-term electricity supply contracts that shield the industry from more recent increases in the price of electricity. Little can therefore be concluded from this *ex post* study.

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[12] The scenario assumes a single homogeneous good and increasing returns to scale. Under these assumptions, the industry location decisions can be very sensitive to varying carbon prices. Note that it is in principle impossible to have leakage rates over 100%, since leakage is defined as the ratio between the increase in emissions outside the country (in response to a domestic carbon policy) and the change in emissions inside the country.

To summarise, evidence on leakage is mixed. Modelling suggests it should be modest overall, but with higher effects in energy-intensive sectors. Actual time-series data is too short to provide much confidence, but at present there is little evidence of significant leakage. However, this may be expected to change, and leakage may be expected to become evident if carbon price differentials rise, as time passes, and as an increasing proportion of emissions allowances are auctioned rather than given away to industrial firms. Early experiments with unilateral carbon prices in a grandfathered context with exemptions and subsidies provide little comfort for the coming decade and beyond.

In consequence, the absence of a clear finding on leakage does not mean that BCAs are not warranted. On the contrary, in addition to having a sound basis in economic theory, they make sense from the point of view of applying carbon prices to consumption rather than to production. And, as will be discussed below, the legitimate fear of leakage, which cannot be rejected by the evidence, provides a strong basis for the threat of BCAs to be considered credible.

4.3 The size of the threat

There is reason to believe that although leakage rates from unilateral policies may not be great so far, using BCAs, and hence pricing consumption rather than production, could have a considerable impact on a number of sectors. Atkinson et al. (2011) estimate the potential size of a border tax on imports according to their embodied, or 'virtual', carbon. The estimates, reported in table 1 below, present the 'effective tariff rate' that each exporting country (row) would face on their goods and services if an importing country (column) placed a USD 50 per ton of CO_2 tax on the virtual carbon content of its imports. Atkinson et al. (2011) note that this illustrative carbon price represents the level of carbon price that a fairly ambitious mitigation target in high-income countries would entail. Prices over EUR 30 per ton were observed in the EUETS in 2008. We would stress, as in section 2, that these 'effective tariffs' are actually the correction of an incorrect price, such that countries without such correction should be regarded as imposing undesirable 'effective subsidies' instead. Nevertheless, 'effective tariffs' provide a useful metric to indicate the scale of the impact of a BCA.

[TABLE 1 ABOUT HERE]

The table shows that exports from China to the EU would face an 'effective tariff' rate of 9.2% of the value of exports. The rate on exports from China to the US would be of the same order of magnitude. We note in passing that China 'exports' of CO_2 to the EU15 are 6.2% of the total produced. The 'exports' of CO_2 to both the EU15 and the US amount to 13.1% of the total produced. This makes China very exposed to a BCA that the EU may impose.

Exports from the US to the EU would face a tariff of 2.9%, while exports from the EU to the US face a 1.3% effective tariff if the US were to impose a similar tax on embodied carbon. Of course such a measure would be unlikely given the fact that the EU is already imposing a carbon price on its domestic producers.

BCAs would have even stronger impacts in selected sectors. For example, an EU BCA on virtual carbon would have considerable impacts on Russia's production and casting of non-ferrous metals such as aluminium, copper and zinc, the production of chemicals, rubber and plastics and iron and steel. In the group of economies in transition, sectors particularly affected include coal and oil mining, aluminium, copper and zinc, iron and steel, and cement. India and China would feel a particularly strong effect in their cement sectors (Table 2).

If the US were to impose a similar border adjustment, it would severely impact Canadian production of natural gas and refined oil, and Mexican production of refined oil and metal ores. In China, cement is particularly exposed, as in India. Russia's non-ferrous metals, South African's iron and steel and non-ferrous metals would also be affected (Table 3).

[TABLES 2 AND 3 ABOUT HERE]

The numbers above ignore the change in exports that would follow the imposition of a tariff. Mattoo et al. (2009) estimate the impact BCAs could have on trade flows and welfare. Their estimates are based on a CGE model [DEFINE?] developed by the World Bank with the purpose of assessing the growth and structural impacts of climate change and policies (multilateral and unilateral) on developing countries. They suggest that a border tax, when applied using emission intensities in the exporting country, would have serious consequences for large developing countries. For example, China's manufacturing exports would decline by one fifth and those of all low- and middle-income countries by 8%; the corresponding declines in real income would be 3.7% and 2.4%[13].

Summing up, the numbers presented above suggest that if regions with domestic carbon pricing schemes, such as the EU, start applying BCAs this would have a major impact on large fossil fuel-based exporters such as China and Russia, but relatively little impact on trading partners such as the USA. The underpinning economic logic of efficiency, the desirability of pricing consumption rather than production, coupled with the political fears over leakage (whether justified or not) suggest that pressure to resort to BCAs will increase over time. Indeed, given the glacial pace of the international negotiations, we would consider it probable that BCAs will actually be deployed. The next section puts this possibility in a strategic context.

5. BCAs and a new strategic direction

[13] Böhringer et al (2011) reach a similar conclusion. The authors go on to say that "from a distributional perspective, the tariffs exacerbate pre-existing income inequality" between exporters and importers. While distributional effects are not the focus of this paper, it is worth noting that they cannot be analysed fully without considering what exporting countries would do in response to a BCA. This issue is discussed thoroughly in section 5.

Our second argument is that BCAs have the potential to be a game changer in supporting, or potentially providing a substitute for, the international climate negotiations. These international negotiations have so far failed to deliver any more than 'roadmaps for agreement'. There are now at least three ways to proceed for countries or regions aspiring to leadership, such as the EU:

(i) Maintain the current, largely unilateral policy regime, risking carbon leakage until a new global deal is implemented in 2020, and accepting major economic inefficiencies and increases in global emissions consistent with likely temperature increases above 2°C;
(ii) Accept that the current regime leaves little chance of achieving the 2°C temperature target, and extend exemptions from domestic carbon prices (e.g. the free allocations in the EUETS and ACPM) and other implicit subsidies to the export sector to protect domestic industry as the world warms; or
(iii) Apply border carbon adjustments to countries that have not taken "equivalent measures" to internalise the carbon externality.

Of the options, (i) involves the substantial uncertainty in UNFCCC negotiations over the coming years, notwithstanding the Durban roadmap to an agreement in 2015, which may or may not be as successful as the Bali roadmap to an agreement in 2009. Option (ii) undermines the very goals of domestic carbon policies (like the EUETS), and while it is perhaps more hard-headed and realistic than option (i), it largely gives up on the chance of preventing serious climate change damages. Hence full BCAs are the only serious option to maximise the impact of climate policy by committed UNFCCC parties and maximise the chances of a sustained policy effort over time.

We accept that countries may be hesitant about disturbing the fragile global trading system — indeed, it is likely that these concerns explain why BCAs have not already been more widely applied. However, we will argue that BCAs are a strategically and political rational choice, in that they take into account what the other parties would do in response. While there is undoubtedly some risk to the trading regime, provided the (economically sound) rationale for BCAs is explained carefully and in good faith, it seems likely that the risks are low. Furthermore, arguably the risks to humanity from catastrophic climate change have both higher probability of occurring and greater impact should they occur, than the risks to the trading regime from BCAs.

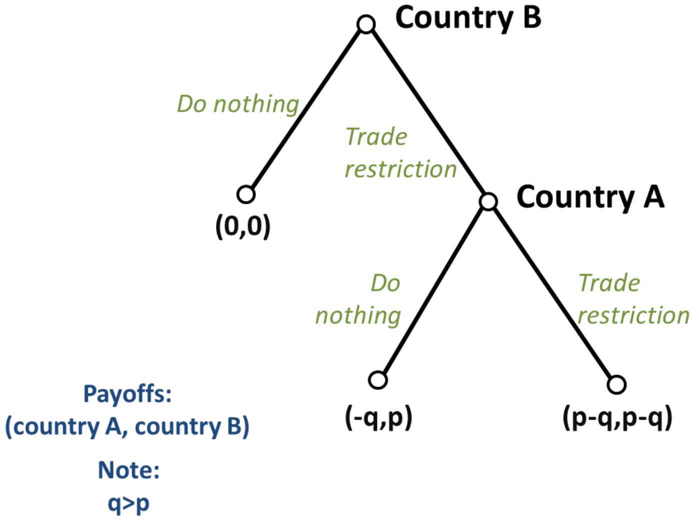
We proceed by first showing the theoretical potential for BCAs to be a game changer by examining the political game theory (section 5.1), second by showing that BCAs can be implemented in a legal context set by the WTO (section 5.2), and third by briefly reviewing a number of practical implementation issues (section 5.3).

5.1 The political game theory of border adjustments

Assessing the impact of the unilateral imposition of a BCA requires considering the strategic interaction with trading partners that are at the same time (potential) parties to a multilateral climate change agreement and parties of a trade agreement. In this section, we develop a simple but insightful dynamic game-theoretic model. Our baseline is a business-as-usual scenario that remains fossil fuel intensive, with significant risks of dangerous climate change. Other outcomes evaluated against that baseline.

Since the game illustrated here is dynamic, we start by describing a portion of it, that we call the 'trade sub-game'. The current world trade system is a combination of levers and ratchets that allow countries to stay in an equilibrium in which all participants experience high levels of welfare compared to a world with no free trade. 'Ratchets' include mechanisms that prevent countries from reverting to unilateral protectionism. The appellate body of the WTO is such a mechanism. If a large country (say country B) puts a trade restriction on imports from another large country (say country A), the affected party can present a dispute to the appellate body. If the appellate body rules against the trade restriction, country A is given the right to retaliate through further trade restrictions. The threat of retaliation is made credible by the fact that country A can reduce its losses from the trade restriction imposed by country B by imposing a further trade restriction. While country A would be better off in the free trade status quo, it would have an incentive to impose trade restrictions once country B imposes one.

Figure 1. International trade game



Note: p represents the absolute values of the domestic gains from a trade measure imposed by a country. q represents the losses imposed on a country by a trade restriction imposed by its trading partner.

The payoffs in the game in Figure 1 capture a key political essence of the trade system: a trade restriction would have winners and losers but would impose a cumulative welfare loss. In essence, a large country imposing a trade restriction is able to have a net *political* gain equal to p while imposing a welfare loss of $-q$ to the affected party. The assumption that $q > p$ implies that there is a net loss in cumulative welfare when a country imposes a trade restriction. We recognise that these payoffs do not map onto basic conventional trade theory (which holds that unilateral reductions in tariffs would benefit the country reducing them).[14] However, this set of payoffs more accurately depicts the political incentives faced by national decision-makers, who are lobbied intensively by the losers of trade liberalisation, and obtain minimal support from the diffuse set of winners.

The description of the trade game illustrates how the world is able to sustain equilibrium with free trade. In the absence of a coordination mechanism, countries would *de facto* move simultaneously as in a "prisoner's dilemma" type of game. It is easy to see that in such case the Nash equilibrium would then be to mutually impose trade restrictions. Trade agreements transform the simultaneous game into a dynamic game through the working of the institutional mechanisms they set up. With the WTO mechanism in place, if one of the two countries moves first and does so against trade rules, the second one can wait to obtain the 'right' to move and retaliate. This credible threat is enough to prevent the first country imposing a trade restriction.

We can now outline the BCA game, shown in Figure 2. This complements the trade sub-game with a dynamic game of complete information in which Country A, (say an Annex 1 entity like the EU, or potentially a large developing country), moves first by either (i) imposing a BCA, or by (ii) not taking any trade action and hoping that negotiations towards a global climate change agreement turn out to deliver. The larger BCA game is a dynamic game encompassing the trade sub-game considered above. Payoffs of the BCA game are presented below the payoffs of the trade sub-game.

The assumed payoffs are based on the costs and benefits of imposing a BCA. Consider first, for the sake of illustration, a large economy that produces all it consumes. If the country imposes a carbon adjustment (which in autarky is domestic by definition), it will gain by reducing the distortion caused by 'over-consumption' of carbon emissions. The cost imposed on consumers (reduction in consumer surplus) and producers (reduction in producer surplus) will be partly offset by the government revenues. In addition, the environmental damage generated by carbon dioxide emissions will be reduced relative to the case with no carbon adjustment, and various other ancillary benefits (local environmental and health benefits) accrued. In a large country, it is not unreasonable to assume that even if the BCA is set at the globally optimal carbon price (rather than just the optional carbon price given damage to the large country), these environmental benefits will more than offset the remaining loss in consumer and producer surplus.

Suppose now that the economy is importing part of what it consumes, and that carbon pricing includes an adjustment at the border. If the economy is large enough, the BCA will cause world prices for the goods subject to the BCA to fall (a

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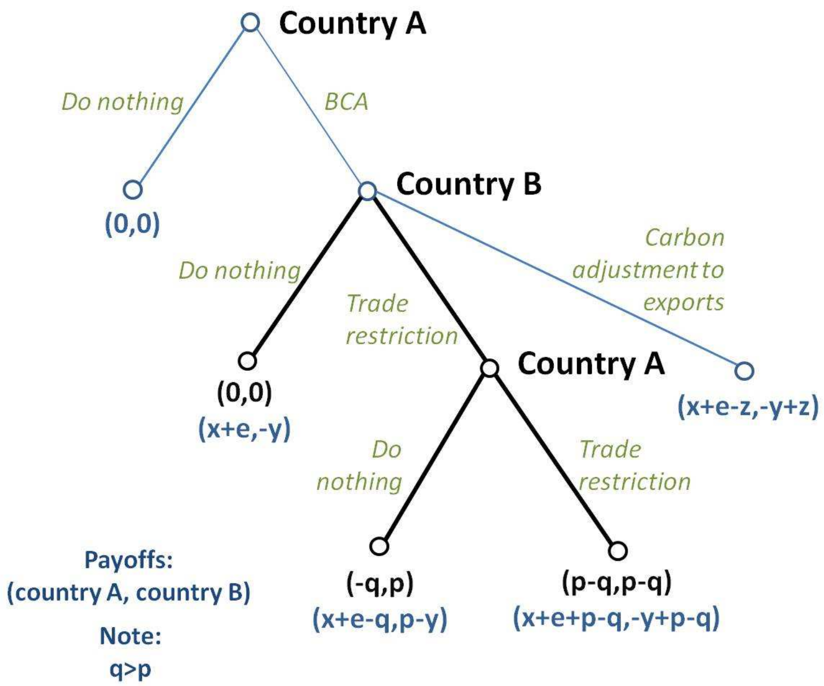
[14] We also recognise that the standard literature (Bagwell and Staiger, 1999; Grossman and Helpman, 1995) identifies that large countries have the incentive to impose "optimal tariffs", exploiting their market power, to capture income from trading partners by improved terms of trade.

"terms-of-trade" gain). In other words, the loss in consumer and producer surplus is being partly offset by terms-of-trade gains (the carbon adjustment will raise domestic resources at the expense of consumers and producers abroad). Compared to the closed economy case, a carbon adjustment including a BCA will be even more advantageous to the country imposing it.[15] Figure 2 illustrates the situation when a large economy (country A) imposes a BCA and receives an environmental benefit, *e,* plus a net economic benefit (terms-of-trade gain minus consumer and producer surplus) equal to *x*. These payoffs apply if country B does not respond, which would be highly unlikely, as we now see.

Next we analyse the welfare effect of the BCA on the exporting country (country B). Assume that the exporting country does not have a preference for a cleaner environment. If the country imposing the BCA (country A) is large, the BCA will lower world prices for the goods it imports. This will in turn reduce producer surplus in the exporting country (country B). The loss will be partly offset by an increase in consumer surplus in country B. However, in general, there will be a net welfare loss in country B (remember that we are assuming that country B does not care about climate change). In Figure 2 we assume that by imposing a BCA, large country A imposes on large country B a net loss (consumer surplus minus producer surplus) equal to *–y*.

Figure 2. BCA game



Note: payoffs in black are the payoffs of the trade sub-game (black lines). Payoffs in blue are the payoffs of the trade sub-game plus the BCA payoffs. *x* represents the absolute value of gains to the country imposing the BCA excluding the environmental benefits. *y* represents the losses imposed on a trade partner by the BCA excluding the environmental benefits. *e* represents the

[15] If the economy is small, then there will be no change in world prices and no terms-of-trade gain. The case is similar to the closed economy case in which government revenues and carbon externality reduction, evaluated at the global level, more than offset the loss in consumer surplus (note that for a small country, supply of imported goods will be infinitely elastic and there will be no loss in producer surplus).

environmental benefits (they are assumed to accrue only to country A). *z* represents net losses to Country A and gains to Country B if B imposes a carbon adjustment on exports. *p* represents the absolute values of the domestic gains from a trade measure imposed by a country. *q* represents the losses imposed on a trading partner by a trade restriction imposed by a given country.

The play of the game is as follows. The game starts with country A choosing whether to impose a carbon price accompanied by a BCA, or to fail to price carbon altogether. Assume that an international court (say WTO's appellate body) has ruled that the BCA is not counter to trade rules. Country B can now (i) do nothing, (ii) retaliate with a trade restriction or, (iii) apply a carbon adjustment to its exports (so as to avoid country A's BCA). Retaliation with a trade restriction leads to the second stage in the trade game, that is, country A will have a 'right' to retaliate with further restrictions on trade or do nothing.

We determine the sub-game perfect Nash equilibrium (SPNE) of the BCA game by backwards induction. Under the assumption that the BCA does not interfere with the payoffs of the trade game, the sub-game following the imposition of a BCA will result in country B preferring to do nothing rather than retaliate. But what if country B can apply a carbon adjustment to its exports, thus forcing country A to reduce its BCA commensurately? Doing so would reduce the cost to country B, in that it will either generate government revenues (e.g. in the case of a carbon export tax) or producer rents (e.g. in the case of quantity restrictions on the amount of emissions exported), which will partly offset the loss in producer welfare caused by the original BCA. We denote these benefits by *z*, and note that it is highly likely that $z > 0$. From country B's perspective, a carbon adjustment to exports will be preferred to doing nothing, which will in turn be preferred to retaliating (given country A's credible threat).

By applying a carbon adjustment to exports, the government in country A will no longer enjoy the revenues it raised through the BCA. Even so, it is likely that this is preferable to not pricing carbon at all. Indeed, provided the environmental benefits plus producer surplus gains exceed the losses (i.e. $x + e - z > 0$), the SPNE is of the game is for country A to apply the BCA and for country B to respond with an carbon export adjustment. An equivalent outcome, with perhaps less hostility, would be for country A to apply the BCA, and then deliver the revenue raised directly to country B, thus moving the game directly to the SPNE outcome.

As a real-world example of these dynamics, consider the current dispute between the EU and the rest of the world (ROW) about the inclusion of aviation in the EUETS as a case in point (see sections 5.2 and 5.3 below). The inclusion of aviation is analogous to imposing a carbon price with a BCA, because the carbon price applies to any flight landing or departing in the EU. ROW will find it optimal to respond to this EU "BCA" with its own carbon export adjustment.[16] This is economically rational, in that it allows the ROW to extract the surplus

[16] For instance, in April 2012, China indicated that it might use revenue from a passenger tax on international flights to cut emissions from the aviation sector. The EU replied that it would consider whether this might be regarded as an "equivalent measure" that would allow exemption from the EUETS. See http://www.irishtimes.com/newspaper/breaking/2012/0419/breaking10.html

from carbon pricing before the EU does. If the ROW's optimal response to a BCA is to respond with a carbon export adjustment, it will be in the EU's interests to introduce a BCA in the first place, rather than "do nothing", and the upper-right branch of the game represents the Sub-game perfect Nash equilibrium (SPNE). This is what appears to be occurring.

To summarise, BCAs build on the trade game currently being played by trading partners. If we accept that the world is currently at the SPNE of the 'trade game', then the introduction of a BCA coupled with an export adjustment in response will be a SPNE provided $x + e - z > 0$ and the BCA does not change the relative size of the payoffs in the trade game (i.e. $p > 0$ always and $q > p$ always). These are relatively innocuous assumptions.

We note that BCAs must be carefully designed. BCAs imposed on protectionist grounds (e.g. to protect jobs) would constitute "murky protectionism" discussed by Evenett and Whalley (2009) and would actually backfire for country A if $z > x + e$. The environment motive is important to the argument, given that it is far from impossible that x (the financial flows to the country imposing the BCA) and z (the financial flows from carbon adjustment on exports in response) are similar in magnitude. For the BCA to be the SPNE, e must be large enough such that $x + e > z$.

We also note that we have not explicitly analysed the full set of actions available to country A. For instance, rather than combining a domestic carbon price with a BCA (which is equivalent to pricing on a consumption basis), country A might combine a domestic carbon price with an export subsidy[17] to level the playing field for industries exporting to countries without carbon pricing. This would not generate the same environmental benefit, e, for country A, because the carbon price would not radiate out through the global economy.[18] Furthermore, it would not generate the same net economic benefits, x, but would instead involve net costs. Such a strategy is thus not optimal in our model. However, if the use of BCAs would actually cause the entire global trade regime to collapse, and result in countries engaging in self-harming retaliatory protectionism, then the underlying trade game is not as we have described it an the optimal strategy on BCAs is different.

Provided it is made clear that the BCA (i) is based on sound economics; (ii) provides a level playing field for domestic and foreign firms; and (iii) is WTO-compliant, our view is that pricing carbon domestically and at the border should not bring the trade regime to the point of collapse. It is economically rational to price externalities, and indeed factor prices need to be correct to guarantee that trade is welfare-enhancing. The price on carbon is particularly important for developing countries — if emissions are not priced properly, the consequences

[17] Providing free permits to emissions-intensive, trade-exposed industries is not the same as an export subsidy, but it is reasonably close if such sectors are largely aimed at export markets.
[18] However, one modification might contribute to achieving this. Suppose the subsidy to exporters in country A were conditional on the importing country B not having a carbon price. This would create an incentive for country B to impose a carbon price, so as to avoid subsidy being applied by country A to exports which compete with outputs produced in country B.

for human welfare, especially in poor countries, appear likely to be extremely serious.

Our simple analysis also abstracts from a range of very important factors of international political affairs. For instance, the private sector response to government actions is also important, as we shall discuss below in section 5.3. However, we believe that this simple model captures the essence of the strategic interaction. In short, a party like the EU has a strong incentive to introduce BCAs to complement their near-unilateral carbon prices. Once the EU does so, the rest of the world has a strong incentive to respond with carbon export adjustments, or potentially even a national carbon price, rather than starting a trade war. And, as we now argue, this is precisely what is currently underway, with aviation as the first theatre of strategic interaction.

5.2 The legality of border adjustments

In addition to compliance with general international law, because BCAs change competitiveness and trade patterns, they are also subject to WTO rules. Debate about whether BCAs are WTO compliant may become heated in the coming 18-24 months, prior to the 2015 deadline for the agreement of a post 2020 following Durban. Anticipating the battle on the horizon, in September 2011, India pre-emptively asked the U.N. to table a proposal to ban on climate-related protectionist measures, including border taxes, at the negotiations in South Africa. Rich countries commented that the issue should be addressed at the WTO rather than UNFCCC talks[19].

One difficulty is that WTO rules do not (and will not) provide clarity whether border adjustments, *in the abstract*, are compliant. A ruling by a WTO Dispute Panel can only be made on a specific border adjustment, and only once it has been implemented and challenged. Compliance will depend strongly on the specific design.

The important point, however, is that it is theoretically possible to design a WTO-compatible border adjustment. The first hurdle is that border adjustments *prima facie* could be considered to breach "non-discrimination" requirements on the grounds that imported goods are "like" domestically produced goods, notwithstanding their greater embodied emissions.[20] So compliance with WTO rules rests on the GATT's "general exceptions". The most relevant likely exemption is article XX(g) that relates to the conservation of natural resources.

[19] One account of the controversy can be found at http://www.twnside.org.sg/title2/climate/news/panama01/TWN_panama.up09.pdf. India's proposal can be retrieved at http://unfccc.int/resource/docs/2011/cop17/eng/inf02.pdf. Developed countries response is summarised in Singapore's official submission that can be found at http://unfccc.int/resource/docs/2011/awglca14/eng/crp30.pdf. The proposal by India and other developing countries has been added as an agenda item for COP17.

[20] GATT Article III:2. It is considered unlikely that the GATT would allow for discrimination on the basis of how a product is produced, but this is a long-standing area of debate.

Previous legal decisions suggest that an article XX(g) exemption would require the border adjustment to account for the comparability of climate change policies in the trading partner countries, and allow individual foreign producers to show that they have exceeded their national domestic requirements, and are thus entitled to appropriate individual treatment. These features are entirely feasible elements of a well-designed BCA.

Other features of a border adjustment that increase the likelihood of compliance include ensuring that:

- Importers pay in the same manner as domestic producers (e.g. purchase and retire permits under the EUETS);
- The terms faced by importers are "no less favourable" than those given to domestic producers;
- The assessment of other countries' climate policies is based on a formal judgment that is able to be appealed and which has involved some degree of input from the affected countries; and
- (Partial) exemption from the adjustment is given to countries who take efforts that are "comparable in effectiveness", even if they don't enact policies of exactly the same form.

Again, all of these features can be incorporated into a BCA. While the issues are complicated, a WTO-compliant BCA can be designed. Further, the political game theory set out above suggests it is likely to be designed and implemented.

The aviation example illustrates some of these issues. On January 2012, the EU incorporated international aviation into the EUETS. Airlines now have to surrender European allowances (EUAs) to cover their annual emissions. While 85% of the permits are allocated to airlines free of charge, polluting airlines will have to buy additional EUAs to cover their liability. The policy has the effect of imposing a carbon price on all flights *to and from* Europe irrespective of destination or domicile of the carrier, and thus operates in a similar fashion to a BCA. Given that a substantial proportion of global aviation starts or stops in the EU, this is an extremely significant policy.

The policy has, not surprisingly, been vigorously challenged by a large number of other countries, including India, the US and China. An important indication of potential retaliation was China's threat in June 2011 to prevent Hong Kong Airlines from purchasing 10 A380 aircraft from Airbus, a subsidiary of an EU aerospace and defence group. More recently, the China Air Transport Association (CATA), which represents four of the country's biggest airlines, has announced they will not pay for the emissions allowances. Political pressure was applied on the EU in September 2011 with a declaration by a coalition of over 20 countries, led by India, that the inclusion of aviation violated international law, following a meeting hosted by India of the non-EU members of the UN International Civil Aviation Organisation (ICAO).

This initial pressure was backed by legal action, with a case launched in the European Court of Justice, the EU's highest court, by US airlines, arguing that the policy broke international law. However, on December 2011, the European Court of Justice held that the inclusion of aviation in the EUETS did not infringe the sovereignty of other states and is compatible with international law. Further, in March 2012, a coalition of US airlines dropped a case brought in the High Court in London.[21]

The fight is thus now relegated to the diplomatic and political level. In February 2012, the Chinese government banned airlines from complying with the scheme. However, in April 2012, China indicated that it might use revenue from a passenger tax on international flights to cut emissions from the aviation sector,[22] an indication of an interest in getting exemption on the grounds of taking "equivalent measures". One might expect other countries to similarly look for the equivalent of a "carbon export adjustment" which will allow them to capture the revenue in country, and claim an exemption from inclusion in the EUETS.

Action by the EU seems unlikely to stop with aviation: the EU has already stated its intention to extend the ETS to the international shipping unless the maritime industry reaches agreement to reduce its emissions. Furthermore, support in the form of free EUAs will be withdrawn in 2013, so the EU shipping industry will likely seek to protect their competitiveness by 'levelling the playing field' at the borders.

5.3 Practical considerations

Given these early disputes, how in practical terms, is the game likely to progress? One would expect a first mover (whether the EU or other region) to start with a BCA on a very specific product (e.g. aviation, or cement) and gradually extent to other carbon intensive sectors. A plausible sequence might be:

1. Start, as has already occurred, by incorporating aviation into carbon pricing, with no exemptions based on the domicile of the carrier. By providing all private carriers with (valuable) free permits that can be sold immediately onto the market, private airlines domiciled in other jurisdictions have an incentive to engage with and comply with the scheme, making it more difficult for their national governments to object.
2. Move to impose a BCA on another carbon intensive industry. Cement is one example. Here, domestic industry might support the protection provided by a BCA, to the extent that allowances must be purchased in future trading phases. Further, cement has the benefit that the calculation of emissions and related technical issues are relatively simple. BCAs look attractive compared to free permits, which have created major welfare losses. For inland cement, where competition is low, they have merely delivered windfall profits to producers; while for coastal cement markets the competition has been too intense for free permits to make much difference (Demailly and Quirion, 2006).

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[21] See http://www.businessgreen.com/bg/news/2164442/airlines-drop-eu-carbon-laws, accessed on 23 April 2012.

[22] Hepburn and Müller (2010) suggested a somewhat similar policy intervention for adaptation based on the principles of responsibility and capability.

3. The likely response is that other countries will follow suit with their own carbon export adjustments or broader carbon prices, and the impetus for a 'sectoral agreement' will increase. This might be agreed through a body such as the World Business Council for Sustainable Development (WBCSD). The likely result is a patchwork of carbon prices that, broadly speaking, apply to cement globally.
4. With the success of the cement BCA, the first mover transitions the focus to the next most attractive industry (e.g. steel).[23]
5. The result of this sequence is that incentives are strengthened for other countries to price carbon. With carbon pricing scheduled for implementation by 2015 in China and Australia, among others, countries without carbon prices will increasingly see other nations collect the rents that accrue from correcting pollution prices. The incentive to capture these rents domestically, rather than see the Europeans, Chinese and Australian take the profits, is likely to prove too attractive to countries with no carbon price.

In this fashion, BCAs increase the pressure for the gradual dissemination of carbon prices around the world. And none of this needs international agreement or the United Nations process, although it could aid and accelerate those processes. Furthermore, as noted above, the economic theory for BCAs is sound; the conceptual notion of pricing carbon consumption rather than production makes sense, and politically the threat of implementation is entirely credible given the dynamic game that ensues.

There is a range of practical objections. An important one is that the calculation of appropriate BCAs will be devilishly difficult. However, the analogy with the environmental valuation literature is a relevant one. Valuing a species is several orders of magnitude more difficult than determining the carbon price differential between two countries. Species valuations are inherently approximate (Helm and Hepburn, 2012). But they are better than an implicit valuation of zero, which is the result if one allows the perfect to be the enemy of the good. Starting with a small number of very heavily carbon intensive industries (cement, steel, chemicals and electricity imports) will make a lot of difference to emissions and to the political game theory of climate policy. Critically, it improves on what is precisely the wrong answer – no BCA at all.

For these industries, there are a number of ways of approximating the embodied carbon. Take the example of steel, exported from China. The energy inputs can be approximated, and we know the share of coal in Chinese electricity generation (around 80%) and we know the emissions from coal power stations. We can then make an estimate of the carbon content of the steel. It would be open for the Chinese exporter to demonstrate that it had, for example, used renewable energy (and it would now have an incentive to do so), and it would also be open to China to impose a carbon price on domestic carbon production, justifying an exemption from the BCA.

[23] Bradley, R. and Baumert, K.A. and Childs, B. and Herzog, T. and Pershing, J., "Slicing the pie: Sector-based approaches to international climate agreements", *Washington, DC: World Resources Institute* (2007), pp. 1-7.]

In the worst case, BCAs could be applied using domestic (as opposed to foreign) emission intensities. This would ensure that foreign producers are not given 'unfair' treatment vis-à-vis domestic producers. Would this put the environmental effectiveness of the measure in peril? Mattoo et al (2009) estimate that border tax adjustment based on the carbon content in domestic production, rather than on the carbon contents of imports, would broadly address the competitiveness concerns of producers in high-income countries without seriously damaging developing-country trade.

In summary, practical objections are capable of being addressed in a pragmatic way that maximises the incentives for inducing the carbon exporter to join a carbon pricing group of countries, in line with what the political game theory analysis above suggests.

6. Conclusions

There is no escaping the fact that the world has made little progress in mitigating climate change. The recent Durban conference postponed effective action for another decade—a period in which the Chinese and Indian economies will double in size at current growth rates. Whilst the search for a comprehensive, legal, binding global agreement remains important, the climate cannot wait. The slow progress is likely to result in at least a 2˚C warming, and there is good scientific evidence to suggest that bigger increases this century are now the most likely outcome, with potentially catastrophic consequences.

In these circumstances, some countries and regions will—and do—wish to take unilateral action. The EU remains the most willing, but it is now confronted with the economic crisis and the related concerns about carbon leakage. Carbon leakage in turn highlights a fundamental problem with Kyoto. Kyoto is based upon carbon production, not carbon consumption. The Kyoto-capped countries can reduce their measured production of emissions by reducing production in the carbon intensive sectors, and then import back the carbon intensive goods.

The potential carbon leakage problem arises because we currently have a multispeed carbon world, some with carbon prices, most without. This creates a trade distortion and undermines the incentives to introduce and increase unilateral carbon prices. The answer is to impose BCAs so that carbon produced domestically is treated on the same basis as carbon embedded in imports, so the carbon content is independent of the geography of its production.

Introducing BCAs corrects the major trade distortion caused by those countries that do not price carbon. These countries are subsidising dirty production, and gaining a trade advantage. BCAs provide a mechanism to put this right, enhancing efficiency, and in the process creating incentives for the countries without carbon prices to introduce them. BCAs provide a pragmatic way of gradually expanding the "coalition of the willing", without having to wait for a top-down global treaty.

Thus BCAs both remove distortions and encourage convergence towards a global carbon price. They can be compatible with the WTO rules, and they can be introduced gradually in a pragmatic way, focusing initially on energy intensive industries. But it is not just that they can be introduced: they need to be introduced if existing unilateral actions are not to peter out. The politics of carbon leakage – as well as the economics – are potentially lethal for carbon pricing, unless the trade distortions are addressed. BCAs are not just an efficiency enhancing addition to the climate change problem: they provide perhaps the only way of making substantial and speedy progress.

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Table 1

Average tariff on imports if virtual-C is taxed at \$50/ton CO_2.

Exports from:	Imports into:															
	Brazil	Canada	China	EU15	EIT	India	Japan	Low income	Mexico	Russia	USA	Other high income	Other middle income	Other Annex 1	South Africa	Average
Brazil	0.0%	4.1%	3.6%	3.3%	3.0%	2.7%	4.1%	2.9%	2.6%	2.5%	3.3%	4.4%	3.0%	4.1%	2.7%	3.3%
Canada	4.9%	0.0%	4.1%	3.9%	3.1%	3.3%	3.3%	3.0%	2.7%	2.9%	2.9%	4.0%	2.9%	3.8%	3.5%	3.1%
China	11.0%	10.0%	0.0%	9.2%	9.3%	11.7%	9.6%	10.7%	9.0%	9.2%	9.3%	10.4%	10.4%	9.8%	10.2%	9.7%
EU15	1.7%	1.3%	1.2%	0.0%	1.3%	1.5%	1.4%	1.4%	1.3%	1.3%	1.3%	1.5%	1.3%	1.5%	1.4%	1.4%
EIT	9.7%	4.9%	5.7%	4.1%	0.0%	6.1%	4.2%	5.9%	4.5%	5.0%	4.7%	5.5%	6.0%	5.3%	6.1%	4.6%
India	7.2%	6.9%	9.5%	7.1%	7.7%	0.0%	7.1%	9.0%	8.6%	8.4%	8.1%	8.0%	8.1%	7.8%	8.7%	7.9%
Japan	1.3%	1.2%	1.4%	1.2%	1.1%	1.5%	0.0%	1.4%	1.4%	1.2%	1.2%	1.5%	1.3%	1.3%	1.1%	1.3%
Low income	3.9%	4.6%	2.3%	3.9%	4.0%	2.7%	3.4%	0.0%	4.5%	4.6%	2.6%	3.2%	4.1%	4.7%	4.9%	3.4%
Mexico	2.9%	2.0%	5.0%	4.4%	4.3%	2.8%	5.4%	5.8%	0.0%	6.4%	1.7%	5.6%	3.0%	5.9%	3.8%	2.2%
Russia	21.0%	10.7%	12.1%	9.6%	8.8%	14.8%	12.6%	14.8%	17.9%	0.0%	14.1%	14.8%	13.6%	14.7%	17.2%	11.0%
USA	3.1%	2.9%	3.0%	2.9%	3.0%	2.8%	2.9%	2.8%	3.0%	2.6%	0.0%	3.0%	2.7%	3.4%	3.3%	2.9%
Other high income	2.5%	2.2%	2.4%	2.3%	2.5%	2.4%	2.3%	2.2%	2.3%	2.5%	2.1%	0.0%	2.3%	2.4%	2.4%	2.3%
Other middle income	7.2%	5.6%	5.2%	5.0%	5.2%	4.3%	4.2%	6.9%	5.8%	5.7%	4.5%	4.5%	0.0%	5.6%	4.3%	4.9%
Other Annex 1	2.2%	2.0%	2.6%	2.2%	2.1%	4.7%	2.4%	2.1%	1.8%	1.8%	2.1%	2.5%	2.4%	0.0%	3.1%	2.3%
South Africa	21.0%	13.0%	15.7%	11.2%	12.7%	13.4%	11.6%	9.7%	16.3%	10.0%	11.5%	14.9%	10.2%	10.5%	0.0%	11.5%
Average	4.4%	3.0%	3.0%	4.2%	3.0%	4.0%	4.2%	4.5%	3.3%	3.2%	3.2%	4.2%	3.3%	3.2%	3.2%	

Note: Average figures represent the trade-weighted average tariff faced by the exporting country (row) or the average tariff imposed by the importing country (column). Virtual carbon trade flows have been estimated using the BTIO approach.

Table 2. Effect of a EU15-imposed USD50 per ton of CO_2 border tax, by exporting country and sector (tax as % of the value of total sector exports)

Sector	BRA	CAN	CHN	IND	JPN	MEX	RUS	EIT	USA	ZAF	XMY	LIY
Crude oil	0.3%	0.0%	0.0%	0.0%	..	0.2%	2.2%	5.8%	0.0%	..	0.3%	0.1%
Coal	..	0.9%	0.6%	0.2%	..	..	5.4%	7.3%	0.7%	3.8%	0.6%	0.5%
Natural gas	..	0.0%	..	0.0%	..	0.0%	3.0%	..	0.0%	..	1.2%	1.0%
Mining of metal ores, uranium, gems plus other mining and quarrying	1.4%	5.7%	3.6%	0.6%	0.2%	3.9%	1.6%	3.4%	1.0%	10.4%	1.7%	2.3%
Production and casting of non-ferrous metals (aluminium, copper, zinc…)	1.5%	1.1%	2.5%	0.8%	0.1%	0.2%	7.7%	4.9%	0.8%	2.5%	1.7%	3.0%
Iron and steel	1.1%	0.3%	2.3%	3.6%	0.1%	0.1%	5.1%	4.4%	0.5%	7.9%	3.7%	4.1%
Cement and other non-mineral metals	0.7%	0.2%	5.0%	6.2%	0.3%	0.2%	2.3%	4.4%	1.2%	5.8%	3.1%	6.7%
Chemicals rubber and plastics	0.6%	0.2%	2.7%	2.1%	0.4%	0.5%	5.8%	4.0%	1.4%	2.3%	2.1%	4.0%
Refined oil	0.1%	0.3%	1.4%	0.2%	0.1%	0.1%	3.5%	1.8%	1.0%	0.5%	1.5%	1.0%
Paper products	0.9%	0.4%	1.6%	2.9%	0.1%	0.1%	1.0%	2.2%	0.6%	0.8%	1.5%	1.9%
Other manufacturing	0.3%	0.1%	1.6%	2.0%	0.2%	0.0%	2.2%	2.1%	0.4%	1.5%	0.8%	1.5%
Agriculture	1.0%	0.3%	0.8%	1.2%	0.3%	0.1%	1.5%	2.3%	0.3%	2.9%	0.9%	0.8%

Note: EIT means 'economies in transition', LIY means 'low income countries', XMY means 'other middle income countries'.
Source: database used by Atkinson et al (2011), based on GTAP data.

Table 3. Effect of a USA-imposed USD50 per ton of CO_2 border tax, by exporting country and sector (tax as% of the value of total sector exports)

Sector	BRA	CAN	CHN	IND	JPN	MEX	RUS	EIT	E15	ZAF	XMY	LIY
Crude oil	0.7%	3.5%	1.4%	0.0%	..	1.8%	0.1%	0.0%	1.3%	..	0.4%	0.4%
Coal	..	0.4%	0.1%	0.0%	..	..	0.1%	0.2%	0.4%	0.0%	0.3%	0.0%
Natural gas	..	8.1%	..	0.0%	..	0.0%	0.0%	..	0.0%	..	0.3%	0.1%
Mining of metal ores, uranium, gems plus other mining and quarrying	0.2%	2.5%	1.7%	0.1%	0.2%	8.8%	0.0%	0.1%	0.1%	0.6%	0.2%	0.2%
Production and casting of non-ferrous metals (aluminium, copper, zinc…)	2.2%	4.1%	1.7%	0.9%	0.1%	1.6%	3.4%	0.2%	0.4%	1.6%	1.0%	0.3%
Iron and steel	2.8%	5.2%	2.4%	3.6%	0.2%	4.3%	1.7%	0.5%	0.4%	3.1%	2.3%	1.2%
Cement and other non-mineral metals	3.5%	3.9%	6.7%	7.8%	0.4%	3.1%	0.4%	0.5%	0.7%	1.8%	3.9%	2.2%
Chemicals rubber and plastics	0.6%	3.7%	3.6%	1.4%	0.4%	1.8%	2.3%	0.5%	0.4%	1.1%	1.7%	1.5%
Refined oil	1.4%	7.1%	1.1%	0.1%	0.2%	9.0%	1.2%	0.6%	0.7%	0.2%	2.2%	0.8%
Paper products	0.5%	2.8%	3.4%	1.4%	0.3%	1.1%	0.0%	0.1%	0.2%	0.2%	0.5%	0.3%
Other manufacturing	0.6%	1.0%	2.0%	1.8%	0.2%	0.9%	0.7%	0.1%	0.2%	0.6%	1.0%	1.0%
Agriculture	0.2%	0.8%	0.5%	0.5%	0.2%	1.5%	0.0%	0.1%	0.1%	0.2%	0.5%	0.1%

Note: EIT means 'economies in transition', LIY means 'low income countries', XMY means 'other middle income countries'.
Source: database used by Atkinson et al (2011), based on GTAP data.