Addressing Carbon Leakage by Border Adjustment Measures

Review of Current Studies

by

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1. Introduction

The Kyoto Protocol to the United Nations Framework Convention on Climate Change was entered into force on 16 February 2005. The Protocol calls for industrialized countries and economies in transition (listed in the Annex B) to limit their aggregate carbon equivalent emissions of the greenhouse gases (GHG), but not requires mitigation from developing countries because of their minor historical contributions to global GHG concentrations and their respective capacity to do so.

When considering limitations on greenhouse gas emissions, policymakers have typically focused on two market-based regulatory mechanisms: taxes and caps with trading. The EU Emissions Trading System (EU-ETS), entered into force in 2005 (Directive 2003/87/EC). All 10,800 covered installations need to surrender allowances for CO_2 emitted during each year. EU-ETS will be extended to 2020 with broadened scope and tightened emission cap in Phase III (2013-2020). In June 2009, US House of Representatives passed the American Clean Energy and Security Act (the Waxman-Markey Bill) that included the creation of a Federal cap-and-trade scheme. In October 2008, the voluntary Japanese Emissions Trading Scheme (JETS) was introduced. Transition to a mandatory cap-and-trade scheme is now planned for 2013 by the new administration.

Domestic climate policies limiting on greenhouse gas emissions in these countries will create an extra carbon price on the combustion of fossil fuels and lead to cost differentials between domestic production and production in countries that are not internalising carbon costs. Such policy differences place firms in countries with strict climate policy in place at a competitive disadvantage in both home and foreign markets. This competitiveness concern, in particular over energy-intensive industries, has centered in the climate policy debates in both US and EU.

Another main concern relates to the competitiveness concern is “carbon leakage”, which generally refers to an increase of emissions in countries without climate policies that can be related to emission reductions in countries with climate policies. Carbon leakage rate can be defined as the ratio of total emissions increase from non-regulated countries to total emissions abatement by regulated countries. If the leakage rate is high, then the effectiveness of climate polices on reducing global emissions will be undermined.

There are three major channels for carbon leakage. The first one is the short-term competitiveness channel, where carbon-constrained industries lose international market shares (through decrease of exports and increase of imports) to the benefit of unconstrained competitors. The second one is the investment channel, where differences in returns on capital associated with unilateral mitigation action provide incentives for firms to relocate capital to countries with less stringent climate policies. The last one is the fossil fuel price channel, where reduction in global energy prices due to reduced energy demand in climate-constrained countries triggers higher energy demand and CO_2 emissions elsewhere, in particular in non-binding countries.

Indicated economically that the best way to address both concerns of competitiveness and carbon leakage would be the completion of a harmonized international climate policy (Stern, 2006; Manders and Veenendaal, 2008), however differences between countries in the level of economic development, political conditions, obligations stemming from historic emissions, and responsibilities arising from future emissions mean harmonization is still a long way off. Among other policy alternatives, the use of offsetting measures at the border to level the playing field is getting popular in policy debates. Border adjustment measures (BAM) in the context of climate policy were initially discussed as an option for the EU to induce the US to join the Kyoto Protocol, however they now feature in discussions in both the EU and the US now vis-à-vis to countries that do not take comparable actions.

Broadly speaking, climate change related BAMs are aimed at restoring international competitiveness through internalising the carbon cost globally, combating carbon leakage, enabling wider and deeper emission cuts domestically and incentivising other countries to join international efforts to cut emissions. Besides the question whether trade measures at issue can effectively deliver the expected economic and environmental benefits left to be answered, BAMs implemented unilaterally may invoke political repercussions and are likely to be challenged by World Trade Organization (WTO) law.

There are two strands of literature debating about the pros and cons of introducing BAM provisions in domestic climate policy to address the concerns of competitiveness and carbon leakage. One stream follows political science analysis focusing on the concerns that trade measures may not be compatible with WTO obligations, poison future climate negotiations, and harm trade relations and international relations in climate negotiations. Another stream of literature focuses on the economic analysis of competitiveness impacts, the scale and scope of carbon leakage and the effectiveness of different BAMs to restore international competitiveness and combat carbon leakage.

The purpose of this report is to review current analyses on anti-leakage measures for the effective implementation carbon pricing policies, with emphasis on BAMs. We focus on four aspects: (i) the scale of competitiveness impact and carbon leakage (Section 2); (ii) the pros and cons of different BAMs (Section 3); (iii) economic analyses of the effectiveness of BAMs (Section 4); and (v) WTO compatibility of BAMs. Major findings and future research agenda are provided in the concluding section. This report can be used by national policy makers who propose for or against using trade measures for domestic climate policy-making. It is also expected to reach the academia by stocktaking of the state of the art and sharpening major issues around BAMs for further discussion.

2. Scale of competitiveness impacts and carbon leakage

The scale and scope of competitiveness impacts and carbon leakage are among critical questions that need to be answered before any policy proposal that is aimed to address these two concerns. There has been rich literature assessing the magnitude of competitiveness effects and carbon leakage at firm, sectoral, national and international levels. Two types of approach are usually applied: i.e. partial equilibrium models focusing on energy-intensive industries and macro-economic models such as computable general equilibrium (CGE) models assessing economy-wide welfare, employment and trade effects. The results on the magnitude of competitiveness effects and carbon leakage vary depending on the design of climate policies (e.g. coverage of installations, emission target setting, the selection of a cap-and-trade system or a carbon tax system, the level of carbon tax in a carbon tax system, and free allocation vs. auction in a cap-and-trade system, etc.), geographical coverage (in particular with or without US participation), the setting of assumptions and parameters, and different types of model applied in assessment.

Rationale of competitiveness effects and mechanisms of carbon leakage

A market-based regulatory system such as cap-and-trade or a carbon tax is typically considered the most cost-effective means of meeting a given climate target for the economy as a whole. Both a carbon tax system and a cap-and-trade system will charge firms, directly or indirectly, for their CO_2 emissions and therefore increase the production costs of manufacturing sectors in particular energy-intensive industries. Increased costs include direct cost, i.e. the cost to abate emissions and/or the cost to purchase allowances for excess emissions or to pay carbon/energy taxes, and indirect cost due to the pass-through of carbon costs from upstream industries (in particular power generations) to downstream users in the supply chain. The relation between the abatement cost and allowances cost/tax paid depends on the marginal abatement cost of a particular firm/industry against the allowances price/tax. Companies will abate up to the point where marginal abatement cost equals to the market price of CO_2. Indirect cost may be presented as more damaging to competitiveness when the cost of secondary energy (e.g. electricity and gas) constituents the major part of an industry's energy costs (such as aluminum). Indicators that are often used to assess competitiveness impacts include a loss of output, reduction in the market share at home and overseas, and a loss of profit, etc.

The degree to which increased carbon costs impact industrial output and employment depends on several variables (Houser, et al., 2008; Tamiotti, et al., 2009):

- Trade exposure;
- Energy intensity of production;
- Direct and indirect carbon costs;
- Potential for energy efficiency improvement;
- Ability to switch to low-carbon energy sources;
- Product demand elasticity, which largely depends on the availability of substitutes (including either the same good from a foreign producer or a different but interchangeable good from any producer) and determines the ability to pass along costs to consumers;
- Carbon costs vs. international transportation costs.

Facing a production cost increase, a firm has several options (Reinaud, 2005). First, the effect is minimal and operations are barely affected if the carbon price is not significant to a firm's cost, (e.g. less energy-intensive sectors). Second, if a firm acts as a price-maker, it can shift the CO_2-related cost to its customers (e.g. power generators). Third, a firm can improve production process to reduce energy intensity or switch to low-carbon alternative energy sources through investment at home country. Fourth, a firm can relocate its production to other countries without such additional carbon cost through investment in foreign countries.

The choice of strategy made by a firm in response to competitiveness impacts heavily relies on timing, among others (Reinaud, 2005). In the short term, most firms have limited ability to improve energy efficiency or switch to low-carbon alternative energy sources. A firm's short-term strategies include a reduction in operational earnings to maintain market share or passing onto the downstream consumers through product price increases to maintain profits margins constant. In the former case, the industry will suffer from profit losses, and in the latter case, the demand in such production will reduce, resulting in a reduction in output. The fate of both strategies depends heavily on two factors. The first one is the availability of substitutes for the product. The second is the competitive nature of the market, i.e., whether the market is monopolistic, oligopolistic or fully competitive. Over the medium and long terms, firms have greater ability to work out lower-carbon sources of energy, develop more energy-efficient technology or relocate its production through foreign direct investment. Most literature analyses the short-term impacts of carbon pricing policy on industrial competitiveness.

In addition, the cost increase due to the carbon price and its relations to the international transportation costs also matter the impacts on particular sectors. In general, international freight costs can act as a barrier to protect domestic production from imports, in particular those which international transportation costs constitute a large part in the total costs of imports, as the case for most energy-intensive sectors. Sectors which unit carbon cost increase will exceed unit international transportation cost may suffer competitive threat of imports.

The viability of the-above mentioned options for a particular industry or a firm determines the fate of competitiveness impacts. Generally speaking, energy-intensive and internationally trade exposed industries are at high risk of competitiveness loss and potentially to carbon leakage, in particular in a short-run perspective. Sectors identified as highly affected in most literature include (see also Box 1):

- Ferrous metals (iron and steel industry);
- Non metallic mineral products (in particular cement);
- Non-ferrous metals (in particular aluminum industry);
- Paper and pulp; and
- Chemicals.

Closely related to the competitiveness concern are carbon leakage effects, which are the result of complex interactions between energy and non-energy markets. In the channel via non-energy markets, there are two correlated mechanisms responsible for carbon leakage effects. First, carbon abatement imposed unilaterally raises production costs affecting the competitiveness of energy-intensive industries. These industries can lose market shares in the international markets in favour of industries located in countries that do not reduce their emissions and causes a corresponding shift in the production of energy-intensive goods at the world level. The trade substitution elasticities (the so-called Armington elasticities) usually represent the intensity by which this mechanism operates. The larger these elasticities the larger the effect of prices on market shares and the larger the leakage rate. The channel through operational leakage is a short and medium-term concern. In addition to the direct effects in goods markets, unilateral carbon constraints can also induce a reallocation of foreign direct investments to non-participating countries. The key parameter in determining the channel through investment leakage is the degree of international mobility of capital. Investment leakage takes place in the longer run but it could be more important than operational leakage in capital–intensive industries like primary aluminum or steelmaking.

The mechanism for carbon leakage through the channel of energy market is complicated. On the one hand, when unilateral carbon abatement occurs in a large country group, the reduction in world demand would cause a fall of the international price of the most carbon-intensive fossil fuels, thus increasing energy demand and carbon emissions in the non-participating countries. The effects of this mechanism depend on key parameters including the supply elasticity of carbon-intensive fuels and the degree of integration in the international coal market. On the other hand, after the implementation of domestic carbon pricing policies, a fall of the international price of oil relative to the coal price would lead to a shift of energy demand from coal to oil. This could induce a fall of the carbon intensity in some large coal consuming countries, like China, leading to negative leakages.

Key indicator used by most literature is the leakage rate (or leakage-to-reduction ratio), which is defined as the ratio of additional emissions in the non-Annex B countries to the emissions abatement achieved in the Annex B countries.

Box 1 Sectors at High Risk of Competitiveness and Leakage Impacts

The iron and steel production is a very CO_2 intensive activity. Approximately 75 percent of the global CO_2 emissions from steel production are related to the use of coke and coal in iron making. In Europe 25, its direct CO_2 emissions amount to 23 percent emissions covered by the trading Directive (IEA, 2003). There are two steel-making processes. One is the integrated route, which is the most capital intensive. The other is produced from recycled scrap using electric arc furnace.

Cement production is a highly energy-intensive activity because of its dominant use of carbon-intensive fuels such as coal in clinker making. The cement industry is estimated to amount to 2 percent of global primary energy consumption (World Energy Council, 1995) and contributes to about 3 percent of the total energy-related CO_2 emissions in EU (Reinaud, 2005). Due to the importance of cement as a construction material and the abundance of the raw materials, limestone, cement is produced worldwide with low product price and relatively high cost of transportation. For long distances the transport cost may even exceed the product price.

There are two main production routes for aluminum production. One is the process for electrolysis of primary aluminum, which is very electricity-intensive, and the other is based on the remelting of aluminum scraps, which is less energy consuming process. Aluminum is a relatively expensive metal because of its high electricity consumption. In 2002, aluminum-related CO2 emissions represented only 2 percent of EU-25's total CO_2 emissions.

The pulp and paper sector represented 5 percent of European CO_2 emissions, relatively low compared to other sectors since market pulp and paper mills are established mostly in European countries with low carbon-intensive electricity generation.

In US, the above five industries represent less than 6% of total direct CO_2 emissions but 14% of total emissions (including both direct from production and indirect from electricity consumption), 3% of national GDP and less than 2% of total employment.

Quantitative analyses on competitiveness effects and carbon leakage

A large body of sectoral literature and partial equilibrium analysis literature focuses on the short-term production channel of competitive loss and carbon leakage for selected carbon-intensive industries. They do not analyse the interactions between energy and non-energy markets. For most CGE literature, they usually separate energy markets from non-energy markets and further divide the non-energy markets into energy-intensive goods and non-energy intensive goods. Some CGE models with a dynamic nature also simulate the channels of investment leakage. In general, existing studies with a wide range of different results cannot provide a coherent view on the magnitude of competitive effects and carbon leakage.

As a representative of sectoral approach literature, Reinaud (2005) indicated that under the assumption of an allowance price of €10/tCO_2 and a full pass-through of the carbon cost in power prices in implementing EU-ETS (Directive 2003/87EC), the impacts on the cost structure of four highly affected industries (iron and steel, cement, newsprint and aluminum) are moderate in the short run. A cost increase, reflecting the impacts of both direct and indirect carbon cost, ranges from 0.7% (steel using basic oxygen furnace) to 2.4% (aluminum) under the scenario of a free allocation covering 98% of emission needs, and from 1.3% (steel using arc furnace) to 3.6% (cement) under a tighter free allocation scenario of 90% emissions coverage. In order to absorb such cost increase, under the strategy of maintaining the market share, industries will suffer reductions in operational earnings from modest to significant: 2.1%-7% under the 98% scenario and 2.2%-8.1% under the 90% scenario. Under the strategy of passing-through the increased cost to consumers, the resulted reduction in demand are moderate ranging from 0.7% (steel with basic oxygen furnace) to 2.1% (newsprint) under the 98% scenario and from 0.8% (cement) to 2.7% (newsprint) under the 90% scenario. In addition, international transportation costs, in its relations to CO_2 cost, play important role in featuring the industry's competitiveness threat of imports at home market. At current levels, freight costs can protect the European industry from imports under the business-as-usual scenario. With the introduction of EU-ETS, foreign imports could compete in European markets for some steel products, and most of all aluminum, for which freight costs would be less than the increased cost of carbon. Reinaud (2008) also assessed carbon leakage for these sectors and find that the steel and aluminum sectors would be expected to have higher leakage rates.

Gielen and Moriguchi (2002) assessed the impact of CO_2 taxes on iron and steel. They find that if only Japan and Europe introduce such a carbon price, emissions reduction in the two countries would be offset by increased production and emissions elsewhere. A leakage rate can be as high as 35 percent in 2020 at a tax level of \$11/tCO_2 and 50 percent by 2030 at \$21/tCO_2.

Partial equilibrium models, though not covering the whole range of mechanisms and aspects through which carbon leakage could occur, fill a gap left by top-down macroeconomic models in terms of high degree of sectoral aggregation, because they are based on more detailed data sets and include sector specific technological patterns or economic geography (Monjon and Quirion, 2010). Sectoral analyses applying partial equilibrium modeling estimated the magnitude of leakage rates varying considerable across studies and across sectors (from several percent up to 70 percent), depending on the specific characteristics of the sector in response to the competitiveness threat, policy options (a carbon-tax or a cap-and-trade system), coverage of participation countries (in particular with or without US), level of carbon price, inclusion of indirect carbon costs from electricity consumption, and Armington elasticities for substitutions between imported goods and domestically produced goods.

Under the policy design of a cap-and-trade system, Demailly and Quirion (2006) and Ponssard and Walker (2008) focus on cement and find relatively high leakage rate around 40 to 70 percent at a price of €20/t CO_2. Demailly and Quirion (2008a) assessed the steel sector and find a leakage rate in the range of 0.5 – 25 percent, with a median value of 6 percent, depending on the parameters and on the policy options. Monjon and Quirion (2010) applied CASE II, a static partial equilibrium model for four sectors (cement, aluminum, steel and electricity), to the EU-ETS in its third phase (2013-2020) assuming a cap at 85 percent of 2005 emissions. They find that even without any "anti-leakage" policy, the leakage rate in case of full auctioning in the EU-ETS is between 5 and 11 percent and thus being a minor problem of concern. However, at the sectoral level, the leakage rate can be much higher (e.g. about 48 percent for steel production with higher Armington elasticities). With a policy simulation of a carbon tax system, OECD (2003) estimated that for an OECD-wide carbon tax, the leakage rate is about 45 percent at a carbon tax at \$25/tCO_2.

These studies, assuming that the competitiveness impacts of an emissions trading scheme would be identical to that of a carbon tax, may however overestimate the EU-ETS impacts on competitiveness and carbon leakage (Reinaud, 2005). Subject to a tax, a firm has no choice but to drastically cut its profits and/or pass-through the extra cost to consumers and to trigger a reduction in profit rates and sales volume. While Grandfathered allowances give industry the flexibility not to pass on the full opportunity cost of CO_2 allowances onto product prices and thus lowering the impacts. Demailly and Quirion (2006 and 2008a) supported this by showing that free allowances allocated based on current output would efficiently reduce the leakage rate from 50 to 9 percent for cement sector and nearly by half for the steel sector.

In contrast to the sector-based models, general equilibrium analyses have both advantages and disadvantages. On the one hand, they are considered valuable in assessing interrelated and balanced transactions between all regions and sectors in the world economy. On the other hand, most studies do not isolate specific industry sectors or sub-sectors as they are limited by the sectoral resolution of the GTAP database on which they are typically based (Monjon and Quirion, 2009). As a result, industry aggregation masks sub-sectoral differences (Reinaud, 2008; Fischer and Fox, 2009).

For analyses based on general equilibrium models, Mckibbin and Wilcoxen (2009) simulated a carbon tax system implemented unilaterally in EU and US, respectively, and found that the real GDP would drop 0.6-0.7 percent in both countries with carbon leakage of about 10 percent for EU and 3-4 percent for US. Bernard and Vielle (2009) analyse the revised EU-ETS with the Gemini-E3 model and conclude that “while carbon leakage may affect specific sectors, with a magnitude of at most a few percent of GHG abatement by Annex B countries, it does not represent a real concern at the aggregate level”. Kuik and Hofkes (2010) assess the effectiveness of border adjustment measures for tackling leakage in the EU-ETS with GTAP-E and find an aggregate leakage rate of 11 percent without a border adjustment. Other models estimated the magnitudes for the global leakage ranging from 5 to more than 30 percent: 3.3 percent (WorldScan, Manders and Veenendaal, 2008), 5 percent (GREEN, OECD, 1999), 6 percent (EPPA-MIT, Babiker and Jacoby, 1999), 8 percent (G-Cubed, McKibbin et al., 1999), 9 percent (GTEM), 10 percent (GTAP-EG, Palstsev, 2000), 11 percent (Gemini-E3), 14 percent (WorldScan, Bollen et al., 1999), 26 percent (MS-MRT), and 34 percent (MERGE4).

In general equilibrium analysis, the results of endogenous variables such as welfare change and CO_2 emissions depend on many direct and indirect mechanisms. Various partial effects may work in opposite directions and therefore influence the overall effect. To address this analytical deficiency, Paltsev (2000) used decomposition analysis to indicate the source and destination of the leakage flows and find major leakages from the US to the Middle East, from EU to South Africa, and from Japan and the US to China. From the perspective of regional contributions to global leakage, the largest induced leakage is from the EU, followed by the US and Japan, accounting for 41%, 29% and 16.6% of global leakage, respectively. China and Middle East countries are the main destination of leakage. From sectoral viewpoint, chemical industry is the major source for the emission migration, followed by iron and steel industry, accounting for 20% and 17% of total leakage, respectively.

Among few studies simulating the risk of reallocation of foreign direct investments to non-participating countries and associated carbon leakage, Burniaux and Martins (2000) indicated that international mobility of capital, the determinant factor influencing the investment leakage channel, has only a small impact on the leakage rate and its effect is conditioned by the value of the trade elasticities. For very low values of the Armington elasticities and a high degree of capital mobility, there will be a net inflow of capital from the rest of the world to the Annex I countries and a negative leakage. Only for high values of the Armington elasticities, there will be a net flow of capital from the Annex I to the non-Annex I countries and increasing the leakage rate. It also suggests that most of the capital reallocation induced by the implementation of the Kyoto Protocol would take place within Annex I countries rather than towards non-Annex I countries, therefore contributing little to carbon leakages (Mckibbin et al., 1999).

Many studies indicated that among three channels of carbon leakage the most important mechanism for leakage is through world energy markets, not trading in non-energy markets (Burniaux and Martins, 2000; Gerlagh and Kuik, 2007; Mckibbin and Wilcoxen, 2009; Fischer and Fox, 2009). Fossil-fuel supply elasticity plays a crucial role in determining the magnitude of leakage through the energy-market channel. In general, the lower the fossil-fuel supply elasticity the higher the scale of leakage. On the one hand, carbon abatement commitments in Annex B countries may decrease the energy demand, which leads to lower international prices for fossil fuels and increases in the fossil-fuel demand and emissions in the non-Annex B countries. On the other hand, the Kyoto agreement might cause a fall in the price of oil relative to the price of coal. Based on a new price ratio, a non-Annex B country might substitute relatively less carbon-intensive oil for carbon-intensive coal. Thus the change in the fossil-fuel demand can even lead to a negative leakage effects (Paltsev, 2000; Oliveira, 1996). With sensitivity analysis, Burniaux and Martins (2000) further pointed out that the size of carbon leakages is sensitive particular to the supply elasticity of high-carbon fuels. The more inelastic the supply of high-carbon fuels (such as coals) the higher the leakage rate. In comparison with the supply elasticity of coal, the supply elasticity of low-carbon energy (such as oil) appears to exert relatively minor influences.

Several caveats need to be noticed from economic analyses. First, most estimates for carbon leakage rate are reported for the scenario where CO_2 emission permits are non-tradable between countries. However, with permits tradable between countries the carbon leakage rate can drop approximately by half (Reinaud, 2005). In addition, the using of flexible mechanisms such as joint implementation (JI) and the clean development mechanism (CDM) offered by the Kyoto Protocol is restricted in most of simulations, except for the WorldScan (Manders and Veenendaal, 2008), which indicated that allowing CDM will lower the emission price considerably and thereby the mitigation costs and competitiveness impacts.

Second, the results from CGE modeling crucially depend on parameter setting, in particular for fossil-fuel supply elasticity and Armington elasticity of trade substitution. In general, the lower the fossil-fuel supply elasticity (in particular for coal) the higher the magnitude of leakage, and the higher the Armington elasticity the higher leakage rate (Paltsev, 2000, Babiker, et al., 2000; Graichen et al., 2008; Monjon and Quirion, 2010). Studies also indicate that fossil-fuel supply elasticity appear more influential in determining leakage rates than the trade substitution elasticity for energy-intensive goods (Martins, 1996).

Third, when the carbon price is assumed to be applied to a larger region than unilateral, the leakage rate may decrease. In particular the assumption with or without US participation may differ in the simulation results considerably. For example, Babiker and Rutherford (2005) found leakage from current Kyoto coalition countries (without US) is around 30 percent and US is the largest destination of leakage, accounting to one-third of the global leakage. Manders and Veenendaal (2008) indicted that given US and other non-EU regions certain caps, carbon leakage is about 3.3 percent, occurring mostly in China and other non-Annex I countries, while without US and other non-EU regions participation, carbon leakage more than doubles (6.7%). Demailly and Quirion (2008b) find a lower leakage rate for cement production than Demailly and Quirion (2006). Main reason is because a larger region is assumed to apply the carbon price in the former case (current Kyoto coalition countries) than in the latter case (EU27).

Key messages

- Economy-wide competitiveness and carbon leakage impacts are estimated to be limited. Leakage rate varies from several percent to 20 percent. However for a few carbon-intensive sectors, in particular basic iron, clinker (for cement), pulp and paper, aluminum and some basic chemicals, the leakage rate may be high and reasonable to cause a policy concern. Experience to date with the European ETS does not reveal leakage for the sectors concerned. However, this does not mean that there will not be any in the future as countries move towards more ambitious mitigation commitments.
- With few participants alone (e.g. EU), the total leakage would be important and the competitiveness component would dominate. However, with a broader set of countries engaged in mitigation (e.g. all of Annex I), the leakage rate would decrease.
- From economy-wide perspective, the carbon leakage related to the loss of competitiveness of individual sectors is small compared to the leakage stem from the energy markets. Even with a very high degree of substitution between non-energy products together with full capital mobility, the leakage effect is rather modest. In addition, the reallocation induced by the implementation of the Kyoto Protocol would contribute limited to carbon leakages.
- Existing studies do not provide a coherent view on the magnitude of competitiveness and carbon leakage impacts. The estimated magnitude of impacts depends heavily on the fossil-fuel supply elasticity and Armington elasticity of trade substitution. In general, the lower the fossil-fuel supply elasticity (in particular for coal) the higher the magnitude of competitive loss and leakage, and the higher the Armington elasticity the higher the competitiveness effects and leakage rate.

3. BAMs: the pros and cons

The first best policy option to address carbon leakage is the pursuit of a global international agreement that imposes a similar CO_2 price signal to all emitters. However, it is difficult to reach such a unanimous agreement at present. A world waiting for all countries to take an action at the same speed may either delay or miss the good timing to act against global warming. Unilateral carbon pricing policy with anti-leakage provisions to level the playing field would be an unavoidable choice however would only be the second or third best option of international climate policy (Reinaud, 2008; Carbon Trust, 2010).

A wide range of policy proposals to address the impacts of asymmetric carbon pricing and carbon leakage across regions for carbon-intensive, trade-exposed sectors (EITE) has been focusing on two broad types (Houser, et al., 2008; Neuhoff, 2008; Reinaud, 2008; Carbon Trust, 2010):

- Cost containment mechanisms: aim to reduce the pressure on carbon-intensive industries by leveling the compliance costs down;
- Trade measures: seek to apply similar costs to competing companies in other countries through the treatment of traded goods at the border.

Free allocation of allowances

"Leveling down" measures can involve many forms, including price caps, borrowing and banking allowances, free allocation of allowances under a cap-and-trade system, tax credit under a carbon tax system, offsets, exemptions, and recycling of the revenue from carbon taxes or from allowances auctioning under both system (Houser, et al., 2008). Each of these measures has its merits and demetrits (Houser, et al., 2008; Reinaud, 2008; Neuhoff, 2008; Carbon Trust, 2010) and recent policy provisions have given greater attention to the free allocation under a cap-and-trade system.

Switzerland's ETS, started in 2008, opted for full free allocation. In Australia, the Green Paper on the Carbon Pollution Reduction Scheme suggests that future Australian scheme should be based on a cap-and-trade model that would include free allowances for the most emissions-intensive trade-exposed activities and lower level of assistance to moderately emissions-intensive and trade-exposed activities (Australian Department of Climate Change, 2008).

In EU, the current EU-ETS (Directive 2003/87EC) allows for free allocation up to 95 percent of allowances for 2005-2007 period and 90 percent for 2008-2012 period. However, in preparing the third phase of the EU-ETS to achieve the mid-term target of 20 percent emission reduction by 2020, the revised Directive (2009/29/EC) changes the way of allocation. First, the emission caps will be centrally determined to avoid over-allocation attributable to the practice of Member States setting their own caps in the first two phases. Furthermore, with some exceptions, a full shift to auctioning for the power sector from 2013 is envisaged, given the sector's proven ability to pass on any additional costs its consumers. For other sectors, there will be a more gradual shift to auctioning from the rate of 20% in 2013, 70% in 2020 to full auctioning by 2027 (Gros, et al., 2010). Along with these provisions aiming at a full auctioning, it contains various provisions to address "sectors at risk" of carbon leakage.

In US, discussions in Congress indicate that protecting the competitiveness of American industries and developing country participation remain important preconditions for US participation in a post-2012 international climate change agreement. Several bills call for a cap-and-trade system and propose for free allocation to maintain the international competitiveness of US manufacturing and avoid additional loss of jobs. The American Climate Security Act (Lieberman-Warner Bill) provides an output-based free allocation to manufacturing facilities including iron and steel, pulp and paper, cement, chemicals, aluminum and other energy-intensive, trade exposed sectors. The Low carbon Economy Act (Bingaman-Specter Bill) also includes free allocation of allowances based on employed workforce. The American Clean Energy and Security Act (ACES), the Waxman-Markey bill, was passed by the US House of Representatives on June 26, 2009. The ACES includes a cap-and-trade program (2012-2050) for the period of 2012-2050 to limit GEH emissions in US. A large percentage of the allowances (75 percent) are provided for free in the early years of the program (by 2026 and over time fewer allowances are distributed free of charge and more allowances are auctioned. Over the life of the program, 40 percent of the total allowances would be auctioned and 60 percent would be distributed freely.

Initial free allocation of allowances has a potential role in containing the compliance cost of covered industries, however depends on the degree to which that industry relies on electricity and natural gas in meeting its energy needs (Houser, et al., 2008). For example, while aluminum producers and large parts of the chemical industry might receive free allowances to cover their direct emissions, most of their increased carbon costs would come from increased electricity prices. Some proposals attempt to compensate for this by offering a surplus of free allowances that can be sold to other sectors to help compensate for rising electricity prices.

Free allocation can compensate investors but may not achieve the underlying aim of protecting output and employment levels and reducing emissions leakage. All allowances have the same value in the market, whether allocated for free or purchased on the market. Theoretically, profit-maximizing manufacturers can choose to cut production and sell allowances that they get for free and even use the allowances revenue to finance relocation of domestic production to other countries which do not have carbon pricing policies in place. This preference for profits over market share would result in a decline in domestic production and output levels over time. Some proposals seek to guard against this incentive by linking allowance allocation to production or employment levels on an ongoing basis, rather than grandfathering in historic production levels.

Providing free allowances to existing producers can help keep older, dirtier domestic production processes in operation while making it more difficult for new entrant to bring cleaner production processes into the market, which will raise the overall economic cost of a cap-and-trade system. In addition, distributing allowances for free may reduce the revenue obtained from allowances auctioning which would be available otherwise for government to increase competitiveness through other means, such as R&D investment or tax reductions.

Border adjustment measures

Another type of measures to level the playing field for domestic carbon-intensive industries and guard against emissions leakage is to apply a similar carbon cost to international competitors through border adjustment measures (BAM). From economic perspective, if leakage occurs because producers face higher carbon prices, then leakage can be avoided when imports and exports are adjusted for the carbon price difference. Thus the full carbon price signal remains intact and creates incentives for innovation in new production processes, products and services and supports the substitution towards lower carbon options. In principle, border leveling can achieve the objective of preserving a level playing field without the efficiency losses associated with "leveling down" through free allocation (Carbon Trust, 2010). In addition, carbon pricing can be transferred, at least partially, to other parts of the world where governments have not implemented carbon pricing policies (Gros, et al., 2010).

Mckibbin and Wilcoxen (2009) summarised several justifications for including border adjustments as a key component of climate policy. BAMs are required for economic efficiency in carbon abatement (Stiglitz, 2006; Kopp and Pizer, 2007; Ismer and Neuhoff, 2007). Another related argument is that adjustments are needed to keep climate policy from being undermined by leakage through relocation of carbon-intensive production to low-tax countries and to protect import-competing goods in high-tax countries (Goh, 2004; Hoerner, 1998; Demailly and Quirion, 2008). There are also a number of papers argue that the approach could be used as a stick to punish countries that did not participate the Kyoto Protocol or as a threat to encourage countries to join a global regime (Brack, et al., 2000; Hontelez, 2008;

Charnovitz, 2003). Finally, there is also a considerable literature debating the legality of BAMs for climate policies under WTO rules (Biermanna nd Brohm, 2005; Brewer, 1998; Frankel, 2005; Goh, 2004; Hoerner, 1998).

European policy makers, in particular France Prime Minister and the European Parliament first put forward the notion of imposing border tariffs on imports from countries that are slow to reduce emissions and targeted them at the US. Other Member States are heavily opposed (e.g. Germany) or skeptical (the UK and the Netherlands) (Houser, et al., 2008). The US has deeply opposed such measures. However as the US starts drafting its own climate policy, legislators are more enthusiastic advocates of such measures which clearly target on China.

In the US, of twelve market-based US climate change bills introduced in the 110th Congress, almost half called for some border adjustment through a requirement that energy-intensive imports surrender permits corresponding to the carbon emissions embodied in them (Reinaud, 2008). The Lieberman-Warner bill, for example, incorporates a requirement for purchasing “international reserve allowances” to cover goods imported from countries that have not undertaken adequate steps to mitigate GHG emissions. The Bingaman-Specter bill includes a weak form of border adjustment by requiring importers to have emissions permits when the emissions in the unregulated (or under-regulated) producing country sector increase above a baseline level. The 2009 American Clean energy and Security Act passed by the House also includes a provision on border adjustment measures. In preparing the third phase of the EU-ETS, the Directive (2009/29/EC) was revised to strengthen the way of allowance allocation gradually towards a full auctioning. In addition, it contains various provisions to address “sectors at risk” of carbon leakage, including adjusting the amount of free allowances and inclusion of importers in the EU-ETS as possible options to address leakage from those sectors deemed to be at significant risk of carbon leakage. By mid-2009, the Commission had indicated that 149 out of the 258 sectors were considered to be at risk of leakage (van Asselt and Brewer, 2010).

BAMs aim to put domestic producers on a level international playing field and to encourage foreign countries to take steps to reduce emissions. Depending on the nature of domestic climate legislation either for a cap-and-trade system or a carbon-tax system, two broad design options for BAMs are commonly distinguished: i) border tax adjustments (BTA), either in the form of a levy on imported goods proportionate to their “embodied carbon” equivalent to a tax under a carbon tax system or the permit price under a cap-and-trade system, or in the form of rebate for exporters at the border; and ii) the requirement for importers to surrender allowances corresponding to the embodied carbon in their goods under a cap-and-trade system.

The design of a particular BAM requires to determine several important factors, such as application to imports or exports only, or a combination of both, the inclusion of indirect emissions from electricity, scope of coverage (sector coverage, and primary products vs. finished goods), the calculation of carbon intensity (the average level in the country of origin, the average level in the country of destination, or the best available technology), and the definition of comparability of national actions. These factors would impact the BAM in terms of carbon price required to achieve a given target, competitiveness effects on protected sectors, the ability to leverage other countries to reduce emissions, WTO legality, administrative costs and complexity, and potential impacts on multilateral climate negotiations. A comparison of BAM proposals in both US and EU is provided in Table 1 followed by some discussions.

Table 1 Comparison of BAM provisions

Legislative proposals	Type of BAMs	Coverage of goods	Inclusion of indirect emissions	Criteria for carbon intensity	Definition of comparability
Bingaman-Specter Bill	Importers to have emissions permits.	Primary products	No.	Sectoral average of covered goods from the country of origin with adjustments to allowances allocated for free and to non-policy induced changes in emissions.	GHG regulatory programs, requirements, and other measures that are comparable in effect, taking into account the level of economic development.
Lieberman-Warner Bill	Importers to surrender allowances from “International Reserve Allowance Program”, a separate pool of allowances.	Primary products in sectors: iron and steel, aluminum, cement, glass and paper.	No.	Sectoral average of covered goods from the country of origin with adjustments to allowances allocated for free and to non-policy induced changes in emissions.	GHG regulatory programs, requirements, and other measures that are comparable in effect.
Waxman-Markey Bill	Importers to surrender allowances from “International Reserve Allowance Program”, a separate pool of allowances.	“Eligible sectors”: energy/GHG intensity is above 5% and the trade intensity is at least 15%; or if energy/GHG intensity is higher than 20%; and manufactured items for consumption.	No.	Sectoral average of covered goods from the country of origin with adjustments to allowances allocated for free.	Comparable action not defined, but include standards: (i) a country has a reduction commitment under an international agreement at least as stringent as that of US; (ii) there is a multilateral or bilateral sectoral agreement; or (iii) sectoral energy/GHG intensity is equal or less than in the US.
Revised EU-ETS Directive	Inclusion of importers in the EU ETS as possible options to address leakage.	Sectors are deemed to be exposed to leakage: the production costs increase by 5% or more and their non-EU trade intensity is above 10%; either the production costs increase by 30% or more or their non-EU trade intensity is at least 30%.	The determination of leakage includes the additional indirect costs from increased electricity prices.	Sectoral average in EU with adjustments to allowances allocated for free.	A notion of comparability of mitigation efforts included: (i) countries representing a decisive share of world production of production in sectors deemed to be at risk; and (ii) countries have firmly committed themselves to reducing emissions in these sectors within the same time frame to an extent comparable to that of the EU and the extent to which carbon efficiency of installations located in these countries is comparable to that of the EU

Sources: Houser, et al., 2008; Reinaud, 2008; Carbon Trust, 2010; van Asselt and Brewer, 2010.

First, all legislative proposals include border adjustment only for imports but not for exported products. However, if the purpose is to mitigate the competitiveness leakage, the BAM should be applied to both imports and exports to ensure the carbon playing field for trade exposed sectors be leveled for both home and foreign markets (Reinaud, 2008). In the case of clinker for cement, an adjustment on imports would probably address concerns about relocation of clinker production. However, in the case of more trade-exposed commodities, such as steel, an adjustment applied only to imports would probably not address leakage concerns and thus requiring adjustments for both imports and exports (Neuhoff and Ismer, 2008).

Second, all of these border adjustment provisions are based on a cap-and-trade system, which increases the complexity in determining the equivalent carbon price than an import tariff proposed under a carbon tax system (Mckibbin and Wilcoxen, 2009). In the case of an import tariff, the equivalent carbon price can be determined on the basis of fixed energy/carbon tax. However, in the case of inclusion of importers to surrender allowances in a cap-and-trade system, the allocation mode must be accounted for, in particular free allocation. To pass the WTO's nondiscrimination test of a BAM, the price of "international reserve allowances" (Lieberman-Warner bill), designed separated from the domestic allowance pool, should not exceed the price of domestic allowances. Second, if free allowances are given to domestic producers, then it is assumed the same treatment would need to be extended to foreign producers. In addition, the fluctuation of allowances price on day-to-day basis also brings difficulty in determining the level to adjust.

Third, the proposed coverage of goods has slowly expanded in terms of both covered sectors and from energy-intensive primary goods to finished items for consumption (van Asselt and Brewer, 2010). The inclusion of finished goods will likely pose significant administrative challenges given the possible different countries of origin of the various components of the finished good (Orszag, 2008).

Forth, three US legislative proposals covers only direct emission costs and the revised EU-ETS Directive includes additional indirect costs from electricity in the determination of carbon leakage and sectors at a risk of carbon leakage. For emission-intensive sectors exposed to carbon leakage, in particular primary aluminum and electric arc furnace steel, electricity cost increases are even more likely to drive loss in competitiveness and relocation than direct caps on emissions. However, addressing indirect emissions costs adds more complexity to a scheme adjusting only for direct emissions (Reinaud, 2008). Identifying the CO_2 contents in electricity used in production could be difficult. The type of fuel used in power generation determines most of the carbon intensity of per unit product. For example, coal emits two to three times more CO_2 than natural gas. In addition, given the dynamic mix of generation sources included in an average power grid, it is difficult to pinpoint which power source was used to produce a specific shipment of goods (Houser, et al., 2008).

Fifth, the determination of carbon intensity of products to be adjusted at the border is a big challenge and has been discussed intensively (see also Box 2). The three US proposals use a nation-wide average for the country of origin to assess the carbon content of imported goods. The EU Directive applies average EU levels. The final carbon footprint of a good depends on the production process employed, the energy efficiency of the capital stock, the fuel source, and the type of feedstock, etc. (Houser, et al., 2008). Gathering all these data for a specific shipment at the border is almost impossible. Determination of carbon intensity based on the average carbon footprint of a category of goods, as provided in all proposals, would be more technically feasible, however inequitable and more difficult to pass WTO nondiscrimination tests in its treatment of products produced with lower carbon intensity like in the countries imposing BAMs. In addition, on the one hand, using the average carbon intensity in the country of origin (as in the US proposals) creates little incentives for exporters to improve their emission intensity and thus undermining one of the stated goals of the trade measure: encouraging emissions reductions in other countries. On the other hand, using the average carbon intensity in the destination country (as provided in EU) will reduce the environmental benefits (Carbon Trust, 2010) of the BAM. A more equitable and environmentally productive approach would be to make assessments at a firm rather than national level, however would involve significant administrative efforts to measure, track, monitor and report emission levels. Setting the adjustment based on best available technology addresses the concern about like products and may allow for a justification under WTO rules.

Finally, international comparisons of the level of efforts that a country actually undertakes to address mitigation are fraught with challenges. When making cross-country comparisons, domestic mitigation efforts, the results of those efforts, the efforts at helping other countries, and the results achieved overseas all seem to be relevant criteria (Philibert, 2005). In addition, some policy actions (e.g. carbon tax) will result in immediate effects, whereas others (e.g. R&D) are expected to bear fruit over decades (Houser, et al. 2008). In addition, developing countries are not necessary to undertake the same level of efforts (or achieve the same results) as underpinned by the Climate Convention. Further, many developing countries have already adopted a number of policies and measures that can easily be compared with those in the US, including ambitious targets for renewable energy, reductions in energy intensity, efficiency standards for vehicles, and reforestation (Reinaud, 2008). For example, China, the source of much of the leakage concerns, is working aggressively to curb the growth and improve the efficiency to its carbon-intensive industries out of local environmental and energy security concerns (Houser, et al., 2008, NDRC, 2010). In 2007, China introduced a temporary export tax at around 25 percent for steel, between 0-15 for aluminum products and 15 percent for cement, most of which already experienced a reduction or cancellation of export value-added-tax rebates. The equivalent carbon price would be around \$65/tCO_2 for steel and \$12/tCO_2 for cement (Reinaud, 2009).

Though BAMs are theoretically demonstrated to be effective in addressing competitive leakage, there are both risks and costs associated with the implementation of unilateral trade measures and should be considered when introducing such strong measures. Three major concerns are around the debate of designing and implementing BAMs: i) their environmental and economic effectiveness; ii) the legality under the system of the World Trade Organization (WTO); and iii) political repercussions and impacts on international negotiations.

First, as noted by Stern Review (Stern, 2006), trade measures are clearly second best to implementing a similar carbon price across the global economy through international agreements. Trade restrictions skew the optimal allocation of the world's resources and the principle of comparative advantage and thus increasing the global cost of achieving the mitigation target set by the Kyoto Protocol. Especially for EU, they are costly because consumers and industries depend on imported inputs which might be the target of a BAM.

Second, the competitiveness impact can be exaggerated and abused. Even where trade barriers may be needed as second or third best solutions, competitiveness provisions risk being abused by import-competing EU industries for purely protectionist purposes unrelated to global warming (Manders and Veenendaal, 2008).

Box 2 Determination of Carbon Intensity

Most climate policy proposals either for a cap-and-trade or a carbon tax system imposes a price on carbon emissions upstream at the point of fuel combustion, i.e. emissions generated directly or indirectly in the production of the good. However determination of carbon intensity in practice is very complex. Measuring direct energy consumption is relatively straightforward. However, computing total indirect energy that is used through production of all the parts and materials from which the good is made requires following the value chain back through intermediate products at every stage. It is more complex when multiple products produced by the same production process are considered. The complexities increase when a good that has been manufactured contains intermediate goods that have a number of different sources across countries. Some studies use input-output tables to estimate direct and indirect energy consumption (Mckibbin and Wilcoxen, 2009).

In addition, emissions embodied in products may vary greatly at the product, company and country levels depending on several factors including (i) production process (e.g. the “mini mills” using electricity to recycle scrap steel for steel production emits one-fourth the amount of direct CO_2 per ton of steel as the blast furnaces and basic oxygen furnaces used in integrated mills); (ii) energy efficiency of the production process (e.g. an ethylene cracker built today can be 30% more efficient than those built in the 1970s); (iii) energy source (e.g. nearly all energy consumed by aluminum production comes from electricity which carbon intensity depends greatly on the type of fuel used in power generation); and (iv) type of feedstock (e.g. ethylene produced from natural gas emits less than half as much CO_2 as those produced from naphtha).

Given the importance of these variables in determining the carbon intensity of products, it is more accurate to assess embodied emissions for imported goods at the border on a case-by-case basis. However it is nearly impossible to implement without the assistance of fairly rigorous emissions monitoring and reporting in the country of origin.

Two broad proposed methods are distinguished. One is based on the national average carbon footprint of a product category in the origin country. While more technically feasible, this approach is inequitable in its treatment of “like products” which carbon efficiency is outstanding than national average and is questionable in its environmental effectiveness. Therefore it may be challenged by the WTO law in particular related to the nondiscrimination principle and the evidence of substantial link between the trade measure designed and the stated climate policy objective (e.g. to encourage emissions reduction in other countries).

A more equitable and environmentally effective approach is to assess at a firm rather than national level. Proposals include individual company declaration confirmed by either some sort of independent certification or labeling of energy/carbon intensity or carbon audit conducted by the importing countries (Houser, et al., 2008).

Third, BTAs may undermine the trust necessary for future international cooperation and agreement on emission reductions. The political sensitivities associated with border adjustments require that they are discussed and implemented in close international cooperation to create trust and share understanding among all parties about the objectives and limitations of BAMs (Neuhoff, 2008).

Forth, the administration of competitiveness provisions is likely to be complex and costly, in particular in determining the carbon intensity and implementing constant monitoring and verification of imports and emissions. This would cause a tension between administrative feasibility and effectiveness in mitigating competitive leakage (Reinaud, 2008).

Fifth, BAMs may be challenged by WTO rules. Generally, under WTO law a proponent of a challenged trade measure is required to demonstrate compliance with nondiscrimination standards, which limit the use of measures that discriminate in favor of domestic products or in favor of one country's imports over another's. They are also often required to show that the measure has been closely tailored to achieve a legitimate policy objective (such as protecting the environment) in a least trade restrictive manner. Protecting domestic producers from foreign competition is not recognized as a legitimate policy objective under WTO law. A BAM provision will need to demonstrate how a trade measure has been designed to achieve anti-leakage and GHG reductions.

Last but not least, different countries might implement domestic measures to address leakage, in particular big countries, which will set a precedence that might be followed by other countries. It will be difficult for subsequent countries individually to implement more efficient schemes, which leads to the lock-in of less efficient policies.

Other Anti-leakage measures

Measures other than BAMs aiming at the issues of industrial competitiveness and carbon leakage related to the implementation of domestic stricter climate policies deserve to be mentioned because a BAM facing a WTO test would be required to examine whether less trade restricted alternative options are available.

Borrowing and banking allowances under a cap-and-trade system: Banking allows companies to emit less than their cap and keep the "spare" allowances for compliance in a later commitment period. Borrowing allows companies to over-emit today in exchange for more ducts later. Borrowing and banking help reduce the compliance costs over the lifetime of the program for the economy as a whole and provide the greatest benefit to energy-intensive industries which consume more primary energy than electricity in particular. Banking can reward over-compliance, while borrowing as valid as banking, depends highly on the degree of confidence in the continuation and strictness of the program in the future. Governments show positive attitude towards applying banking but are cautious in using borrowing.

Tax credits: As in the case of free allocation under a cap-and-trade system, tax credits reduce the carbon tax burden that firms face in a carbon tax system. Their effectiveness also depends on how much industries consume primary energy vs. secondary energy. In addition, the environmental cost of such a measure is high because it removes the incentive to reduce emissions.

Offsets: Offsets allow participants to implement emissions abatement measures in other jurisdictions or non-covered sectors. Credits from these activities could be surrendered for compliance purposes in lieu of emissions reductions under either a cap-and-trade system or a carbon tax system. Since it allows companies to seek a wider range of abatement options, many of which would be cheaper than those available in their own facilities, they will tend to reduce abatement costs. Offsets can both provide some degree of industry protection and reduce overall economic costs while maintaining the environmental integrity of the policy.

Exemptions: Exemptions allow carbon-intensive manufacturing industries to be excluded from the list of regulated entities. Though reducing the compliance costs of covered sectors, they increase compliance costs for the economy as a whole by removing some low-cost abatement options from the system.

Revenue recycling: Using part of the allowance auction revenue under a cap-and-trade system or tax revenue under a carbon tax system to offset healthcare or retirement costs for carbon-intensive manufacturers would address employment concerns more specifically than would free allocation.

Key messages

- Free allocation does not come for free, but at the expense of wider implications stem from increased carbon price required to achieve the given emission target. For environmental effectiveness, whether leakage impacts will be alleviated or deteriorated depend on the degree to which industry relies on electricity and whether carbon-intensive manufacturing sectors are compensated by free allocation for both direct emissions and indirect emissions. Free allocation may not be the only long-term option for tackling carbon leakage and hence need to consider other options.
- Theoretically speaking, border adjustments are economically efficient and can be designed so as to be compatible with WTO rules. However, if pursued unilaterally, they risks repercussions for international cooperation on climate policy. Border adjustments can be implemented effectively only if they are pursued in an international context that ensures trust and shared understanding of the purpose of the measure and limits scale and scope to address leakage concerns clearly.
- Several important factors determine the detailed design of a BAM and have substantial impacts on its economic and environmental effectiveness, the ability to leverage global emission reductions, WTO legality, administrative costs and complexity, and potential impacts on multilateral climate negotiations. Such factors include an application to the full trade flow (both the inclusion of indirect emissions from electricity, scope of coverage, the calculation of carbon intensity, and the definition of comparability of national actions.
- The choice between “leveling down” and “border leveling” and how these measures are approached may have implications for the world’s progress on carbon pricing efforts. It will be important to ensure that approaches to tackling carbon leakage are not locked-in to the wrong path, but rather create incentives to move the world faster towards more effective global action.

4. Effectiveness of BAMs: Economic analysis results

Economic analyses on border adjustment measures (BAM) focus on the effects of BAMs on competitiveness and carbon leakage. These two major concerns, arising from the implementation of carbon pricing policies in a subset of all emitting countries, are usually translated into quantitative indicators or indices, including changes in trade flows (imports and exports), terms of trade, production output, national welfare, amount of global emissions, rate of carbon leakage, and employment. Carbon pricing policies simulated are either a carbon tax system or a cap-and-trade system (in particular the EU-

ETS). Most analyses assume that the permit price (uniform across sectors) under a cap-and-trade system is equivalent to the tax rate in a carbon tax system. Border adjustment measures are broadly categorised into two types. One is related to the reduction in compliance costs, in particular free allocation of allowances and exemptions from an emission cap. Though this type of anti-leakage measures are not a direct border adjustment, they are proposed aiming at the correction of price distortion in international trade due to the unilateral implementation of carbon pricing policies. The other is border tax adjustment (BTA) measures. Two particular kinds of adjustment are distinguished. One is import tariffs on carbon-intensive imported goods aiming at levelling the playing field for imports at home market. The other is export rebates on carbon-intensive exported goods to levelling the playing field for exports at foreign markets. A wide range of anti-leakage measures are designed based on a mix of BAM options for economic simulations. Some analyses focused on one type of BAMs (e.g. import tariffs), while a few studies tried to compare different types of BAMs or different options within one type of BAMs. Most literature has a sectoral focus on energy-intensive, trade-exposed sectors (EITE), which are recognised as sectors at a high risk of competitiveness and carbon leakage.

There are general two types of models. One is CGE type, mostly having a multi-region, multi-sector, static feature. Another type is partial equilibrium (PE) model focusing on specific EITEs. The analysis results varied greatly between using CGE and PE and among different CGE models, based on which different (or sometimes opposite) insights on the impacts of BAMs are provided. Though greatly influenced by model and parameter settings, the environmental and economic effectiveness of BAMs depends to a large extent on the following common factors: i) the coverage of participation countries; ii) the coverage of goods/sectors; iii) the inclusion of marginal climate policy costs (direct and indirect costs); iv) the application to all trade flows (imports and exports), and v) carbon intensity adopted (domestic intensity, origin country’s intensity or the best available technology), among others. In addition, different countries have different national circumstances (such as carbon intensity, structure of trade flows, carbon-dependency of electricity generation, production technology employed, etc.), which in turn reflecting different impacts across countries when applying the same policy measure.

This section is to compare various economic analyses (two of them using PE and others using CGE) in terms of their research purpose, type of model, country and sector coverage, specific policy design, major assumptions, as well as the impacts on carbon price, national welfare, employment, trade flow and production, and carbon leakage. The results are listed in Table 2 and Table 3. We further summarise some common results and discuss the caveats for applying them to guiding policy-making.

Table 2 Economic Analysis Approach

Reference	Main Objective	Type of Model	Country Coverage	Covered Sectors	Anti-leakage Policy Measures	Major Assumptions
Babiker, et al. (2000)	Assess the economy-wide vs. sectoral impacts of EXEMP.	EPPA-GTAP: recursive dynamic multi-region, multi-sector CGE.	Focus on USA, with other eleven regions including EU, JPN, OOE, FSU, EEUR, BRA, CHN, IND, energy exporting countries, dynamic Asian countries, and ROW.	Nine sectors: 4 non-energy/5 energy.	Different EXEMPs.	Kyoto targets for all Annex B with USA. ETS in all Annex B but no trading among countries. Sectoral exemptions only in US.
Babiker and Rutherford (2005)	To compare and contrast the effectiveness and the welfare implications of various BAMs.	Static multi-region multi-commodity CGE.	Thirteen regions: USA, CAN, JPN, EUR, OOE, FSU, CEA, IND, CHN, BRA, dynamic Asian countries, Mexico and OPEC, and ROW.	Ten commodities: 5 energy goods, one energy-intensive sector, one non-energy-intensive composite, and a savings good.	EXEMP, REB, VER and IMT.	Kyoto targets on CO_2. Two employment regimes: neoclassical full-employment and Keynesian type of sticky wages and unemployment.
Peterson and Schleich (2007)	Analyse the economic and environmental effects of BTA measures in EU.	GTAP-E: static CGE model based on GTAP6.	Eleven regions: focusing on EU-ETS and diving EU into EU15 and ROEU, together with other countries including AUS, JPN, USA, CHN&IND, Middle East and Africa, Rest of Annex B, ROA, Rest of Eastern Europe and FSU, Rest of Central and South America.	Seventeen commodities: 5 energy goods, 5 energy-intensive sectors, 5 non-energy-intensive sectors, and trade and transportation	IMT; REB; banking allowances by ROEU.	Kyoto mitigation targets for the Annex B and a cap-and-trade system across the Annex B except for the rest of Eastern Europe and former Soviet Union. No “hot air” allowed. Carbon tax is equivalent to the value of CO_2 permits. BTA only to non-Annex B countries. No JI nor CDM credits.
Fischer and Fox (2009)	Compare different anti-leakage policy measures.	Two-country two-sector PE model with parameters calibrated based on GTAP-EG in GAMS (Fisher and Fox, 2007 and 2009).	Two countries: USA and CAN.	Four sectors: electricity, refined petroleum products, chemicals, and nonmetallic minerals.	IMT; REB; BTAFULL; HREB.	Carbon tax is assumed as fixed carbon price.

Note: REF: reference case (carbon pricing policy without any anti-leakage measures); AUT: auctioning of allowances; BTA: border tax adjustments including import tariffs and export rebates; BTAFULL: both import tariffs and export rebates for both direct and indirect emissions; EXEMP: sectoral exemptions from emissions cap or from carbon tax; GFA: grandfathering allocation; IMT: import tariffs; HREB: home rebates for all domestic production; OBA: output-based free allocation; OBAFULL: output-based free allocation for all goods for both direct and indirect emissions; OBA/EITE: output-based free allocation for EITE goods for both direct and indirect emissions; REB: export rebates; VER: voluntary export restraints.AUS: Australia; BRA: Brazil; CAN: Canada; CEA: central Europe; CHN: China; EEUR: east Europe; EUR: Europe; FSU: former Soviet Union; IND: India; KOR: Republic of Korea; LDC: least developed countries; MEX: Mexico; OOE: other OECD countries; ROA: Rest of Asia; ROEU: EU countries other than EU15; ROEUR: rest of European countries; ROW: rest of the world; USA: the United States of America.

Table 2 Economic Analysis Approach (Cont.)

Reference	Main Objective	Type of Model	Country Coverage	Covered Sectors	Anti-leakage Policy Measures	Major Assumptions
Mckibbin and Wilcoxen (2009)	To assess the economic and environmental effects of BTA.	G-Cubed model: dynamic stochastic CGE model for multi-regions and multi-sectors.	Ten regions: USA, JPN, AUS, EU, OOE, CHN, IND, LDC, EEUR&FSU, and OPEC.	Twelve sectors: 7 non-energy/ 5energy.	BTA: focusing on BTA in EU against US and other regions, and BTA in US against China and other regions, based on the carbon intensity in US and China, respectively.	No specific emissions target but a carbon tax assumed at $20/tC, rising by $0.5 per year to $40. Recycling of revenue from border tax. Border adjustment based on embodied emissions calculated by IO model. Short-run unemployment based on the demand for labor.
Monjon and Quirion (2010)	Compare the efficiency across several “anti-leakage” policy options.	CASEII Model: a static and partial equilibrium model.	Two regions: EU27 and ROW.	Four sectors: cement, aluminum, steel and electricity.	BTA: BTAFULL, IMT, BTAFULL/Direct, BTAFULL/EU average, IMT/Direct; OBA: OBFULL, OB/EITE, OB/EITE/Direct. Low and high Armington elasticities.	A cap at 85% of 2005 emissions by 2016 for EU under EU-ETS. Other countries do not implement a climate policy. No JI nor CDM credits.
Takeda, et al. (2010)	Compare different BTAs and between BTA and free allocation and their effects on Japanese economy.	GTAP-EG: static CGE model based on GTAP7	Fourteen regions: USA, CAN, JPN, OOE, EU27, FSU, ROEUR, CHN, KOR, IND, BRA, ROA, MEX&OPEC, ROW.	27 sectors: fossil fuel sectors and non-fossil fuel sectors	IMT/Foreign intensity, IMT/Japanese intensity, REB/Japanese intensity, REB/EITE/Japanese intensity, and OBA.	A cap-and-trade system in JPN only (30% down from 2004 level, equivalent 25 reduction of 1990 level).

Table 3 Comparison of Economic Analyses on Anti-leakage Measures

References	Policy Measures	Carbon Price	National Welfare Impact	Employment Impact	Trade Flow Impact	Carbon Leakage
Babiker, et al. (2000)	Different EXEMPs.	Economy-wide permit price is $307/tC in 2010.	Range from 32% to 300% loss compared with economy-wide climate policy in the US.	Relatively small gains to target industries but at very large cost to the US economy.	Greatly benefit energy-intensive industries but slightly worsen other industries in the US.	Not considered.
Babiker and Rutherford (2005)	EXEMP, REB, VER and IMT.	Except for Japan, exemptions have the highest carbon tax, and except for Japan and EU, VERs has the lowest carbon tax. Japan has the highest tax under the voluntary export restrains and Japan and EU have the lowest tax under rebates.	For Kyoto coalition: IMT is welfare improving while others are welfare worsening with VER the most welfare costly. For Non-coalition: VER is least welfare costly and IMT is most welfare costly. Globally, rebates and exempts are least welfare cost options.	Not specified	Only the exemptions and rebate cases ameliorate the production and trade effects in Kyoto coalition countries.	In general BAMs may not be effective to cure leakage. Carbon tax without BAMs (30%), exempts (19%), export rebates and import tariffs (28% each), voluntary export restraints (38%).
Peterson and Schleich (2007)	BTAs.	Increase 0.5% (ET-ETS coverage) and 1% (extended sectoral coverage)	1-2% welfare increase compare to those without BTAs.	Not considered.	Import tariffs are effective in neutralising the increased import competition in EU15, but not that effective in the ROEU. Export rebates are effective in not only neutralising but also reversing the loss in export competitiveness for EU15, but little effective in the Rest of the EU.	3-6% reduction in leakage (EU-ETS coverage), and 8-13% reduction (extended sectoral coverage) compare to those without BTAs.

Table 3 Comparison of Economic Analyses on Anti-leakage Measures (Cont.)

References	Policy Measures	Carbon Price	National Welfare Impact	Employment Impact	Trade Flow Impact	Carbon Leakage
Fischer and Fox (2009)	IMT; REB; BTAFULL; HREB.	Fixed carbon tax at \$50/tC.	Not considered.	Not considered.	All BAMs help protect domestic production from carbon pricing. In particular, IMT only affects imports at home market, export rebates affect home good in foreign market, and home rebates discourage substitution toward foreign goods at both home and abroad, but also discourage domestic energy conservation. BTAFULL seem better performed.	The largest share of leakage arises from energy channel. None of the BAMs necessarily reduces global emissions. Relatively speaking, BTAFULL would be most effective for avoiding leakage, followed by home rebates.
Mckibbin and Wilcoxen (2009)	BTA in US and EU, respectively.	Start at \$20/tC, rising by \$0.5 per year to \$40.	BTA has little effects on offsetting the welfare loss under carbon tax introduced in EU and US, unilaterally.	Not considered.	Because the level of adjustment is small, they have little effect on import-competing industries.	BTA would be effective at reducing leakage, but leakage is very small even without the adjustments.
Monjon and Quirion (2010)	Full auctioning with BTAs and OBA.	From 24 € /tCO_2 (full auction w/o BAMs) to 48 €/tCO_2 (OB full)	Not considered.	Not considered.		Full auction without BAMs: 5-11%; OBA scenarios: 1-4%; BAMs scenarios: negative leakage.
Takeda, et al. (2010)	Full auctioning with BAMs (two IMTs, two rebates, and OBA).	From less than 100\$/tCO_2 in the reference and all BAMs except for OBA (130\$/tCO_2).	Compare to reference- Welfare improving: two IMT options; Welfare worsening: OBA; Little impact: two rebates options (little worsening).	Not considered.	All measures alleviate the competitiveness impacts to some extent. Impacts on production (EITE): OBA is the most effective, followed by two rebate options, then two IMT options. Impacts on imports (EITE): IMT/Foreign intensity is the most effective, followed by IMT/Japanese intensity, two rebate options and OBA. Impacts on exports (EITE): OBA is the most effective, followed by two rebate options, then two IMT options.	Leakage rate: reference (25%) and all BAMs reduce leakage to some extent. IMT/Foreign intensity is the most effective, followed by OBA, REB/Japanese intensity, REB/EITE/Japanese intensity and IMT/Japanese intensity.

For sectoral exemptions from carbon pricing for energy-intensive sectors, several studies (Babiker, et al. 2000; Babiker and Rutherford, 2005) indicated that it can reduce carbon leakage effectively and can greatly benefit target industries in terms of ameliorating the production, employment and trade effects, however at the cost of losing economic efficiency of policy implementation in terms of cost increase to other sectors and a decrease in regional welfare. The cost of exemptions increases with the target level of emission reductions and with the share of the exempted sectors in economic activity and total emissions (Bohringer and Rutherford, 1997; Paltsev, 2000) and tends to rise substantially over time (Babiker, et al., 2000).

For BTA measures, different studies have different observations. From the perspective of national welfare, most studies indicated that they are welfare improving for countries which implement carbon pricing together with BTAs, however the effects is very small. Some studies indicated only import tariffs is welfare improving while export rebate is welfare worsening (e.g. Takeda, et al., 2010). Other studies indicated that BTA measures have little impact on welfare improving (Mckibbin and Wilcoxen, 2009). From the perspective of international competitiveness effects, most studies indicated that both import levies and export refunds restore loss in competitiveness to a certain extent. In particular, import tariffs affect imports at home countries and export rebates affect exports at foreign countries. A combination of import tariffs and export rebates (in particular for EU, which the largest impact on trade is a loss in export competitiveness) performs better to address international competitiveness for industries at high risk of impacts. However, other studies indicated that BTA measures implementing in EU will not benefit all EITE sectors in EU15 nor in other EU countries. A few of studies showed that import tariffs have little effect on import-competing industries because the level of adjustment is small. From environmental perspective, some studies indicated that BTAs are effective to address carbon leakage while others doubted that BTAs may not be effective.

For studies comparing and contrasting different BAMs, Babiker and Rutherford (2005), by using CGE model, indicated that from an overall perspective of the coalition bound with the Kyoto targets, both exemption and voluntary export restraints are welfare worsening while rebate and carbon tariff are welfare improving options. Exemption increases the abatement burden of the other sectors in the economy, while voluntary export restraint arrangement simply transfer rents to the non-coalition countries. Voluntary export restraints are by far the most expensive option for the Kyoto coalition states both individually and as a group. Exemption is welfare worsening for the coalition group however is welfare improving for less energy-efficient members (e.g. other OECD). The rebate and carbon tariff are welfare improving to the coalition, however Canada is worse off with the rebate and Japan is worse off with both the rebate and the carbon tariff. This indicates that coalition countries may have different preferences over candidate BAMs. From an overall coalition perspective the carbon tariff would be most preferred. For non-coalition regions, except for the carbon tariff option which has sever welfare implications, other three policy options, in particular voluntary export restraints, are welfare improving. From the preservation effects on energy-intensive industries, the exemption and rebate cases are the best candidates across different BAMs. In summary, from overall economic effectiveness point of view, the rebate policy buys the Kyoto collation states more in terms of energy-intensive industries and employment, whereas the tariff policy buys them more in terms of welfare. In general BAMs may not be effective to cure leakage. Exemptions are effective to carbon leakage, while BTAs have little effect and voluntary export restraints may even increase carbon leakage.

Takeda, et al. (2010), using CGE model focusing on Japan, indicated that among different BAMs two import tariff options are welfare improving, while two rebate options are little worsening and output-based allocation is welfare worsening option. All measures alleviate the competitiveness impacts to some extent. For the impacts on the production of EITE industries, output-based allocation is the most effective, followed by two rebate options and two import levy options. For the impacts on import-competition goods, import levies are the most effective (in particular based on foreign intensities since most of EITE industries in Japan have lower intensity than foreign countries), followed by two rebate options and output-based allocation. For the impacts on exports, output-based allocation is the most effective, followed by two rebate options and two import levy options. For anti-leakage effect, import levy based on foreign intensities is the most effective, followed by output-based allocation and others.

Monjon and Quirion (2010), using partial equilibrium analysis, simulated five measures of BTAs and three measures of free allocation under the EU-ETS third period. They showed that all these anti-leakage policies are successful in reducing the leakage rate significantly to below 4% compared with the case of full auctioning without any BAMs (5-11%). Among the two families of anti-leakage policies, border adjustments are more efficient, which can entail negative leakage due to the reduction of EU demand for carbon-intensive goods, no matter whether adjustments are for imports not exports, or for direct not indirect emissions. Comparing with border adjustments, output-based free allocation schemes lead to higher leakage rates which however remain very limited. The most efficient measure (leakage rate at 1% only) is the one with auctioning in the power sector and output-based allocation in other energy-intensive sectors covering both direct and indirect emissions.

For the impacts of BAMs on non-Annex I countries, most studies indicated that BAMs are welfare worsening for non-Annex I countries, in particular China. However the effect is too small to act as a credible threat to non-abating countries. Compare to the situation of a global agreement in which non-Annex I countries also have certain targets, income losses for non-Annex I due to BTAs are less. In summary, BTAs impose extra costs on non-complying, but not enough to tip the balance (Babiker and Rutherford, 2005; Manders and Veenendaal, 2008).

Several caveats need to be discussed.

First, the calculation of emissions embodied in imports by tracing the origin of production at product or firm level is a challenge in both technical and practical terms. It is particular difficult when indirect emissions from domestic power generation and globally tradable intermediate inputs are taken into account. For economic analyses, the selection of the benchmark for calculating emissions embodied in imports can also influence the simulation results. Peterson and Schleich (2007) used constant emission intensity for each type of energy commodities (coal, oil, gas, and petroleum and coal products) across regions. Since the CO_2 intensity of coal and coal products used in power generation and production in developing countries (such as China) may be higher than those in Annex B countries (such as Japan, EU and US), the carbon contents of imports from developing countries might be underestimated. This will lead to an underestimation of emissions subject for tax adjustment at the border and therefore the welfare gain by using adjustment measures at the border. Yan and Whalley (2009) used the emission intensity of importing countries which implement carbon pricing and border adjustments. This may also lead to an underestimation of the emission intensity of imports from developing countries and thus the underestimated emissions subject for tax adjustment. Some other studies used the average sectoral emission intensity of exporting countries (e.g. Takeda, et al., 2010). However, firms exporting from developing countries (such as steel firms in China) usually represent higher or the highest level of technology in the country and can have equivalent carbon-intensity as in developed countries (Houser, et al., 2008). Using the average emission intensity of exporting countries may lead to an overestimation in emission subject for tax adjustment.

Second, the design of policy scenarios simulating carbon pricing can influence the results from across economic analyses. Most analyses abstract from accounting for the use of JI and CDM credits by governments. However, employing these instruments is likely to bring down marginal (and total) emission reduction costs in EU and other Annex B countries (Peterson and Schleich, 2007; Reinaud, 2008; Monjon and Quirion, 2010). In addition, some analyses allow trading of emission permits among Annex B countries while some others do not. Emission permits tradable among Annex B countries will reduce both marginal and total emission reduction costs in the Annex B countries and may influence the analysis results substantially (Babiker, et al., 2000, Peterson and Schleich, 2007; Fischer and Fox, 2009). Further, most studies assume a single carbon tax across all sectors is equivalent to the allowance price in the case of a cap-and-trade system. Using a single carbon tax implies that the emission targets between sectors within the regulated region will be allocated optimally. However, this may, for example, differ from the outcome the allocation process in the second phase of the EU-ETS where trading sectors tend to get more allowances than would be optimal from a cost-efficient perspective (Peterson and Schleich, 2007; Fischer and Fox, 2009). Moreover, whether EU countries other than EU15 bank their excess permits will influence the analysis results significantly. If these countries sell all of their excess permits, the EU15, Japan and the rest of the Annex B can reduce emissions by 4.9%, 3.1% and 5.7% respectively comparing with the reduction targets (2005-based level) of 6.9%, 12.7% and 25.1%, respectively. This lower level of emission abatement leads to a lower carbon price at roughly half of the price and less carbon leakage (about 70% down) than if non-EU15 EU countries bank all of excess permits (Peterson and Schleich, 2007).

Third, the inclusion of international trade and transport margins in the model creates a wedge between producer and purchaser prices, which is particular relevant for some of the sectors such as cement or lime producers (Peterson and Schleich, 2007). As mentioned in Section 2, international freight costs can generally act as a barrier to protect domestic production from imports. However sectors with unit carbon cost increase exceeding unit international transportation cost may suffer competitive threat of imports. Peterson and Lee (2005) have shown that the impact of carbon taxes on prices and leakage may be significantly overstated if the trade and transport margins are not explicitly modeled.

Finally, from methodology viewpoint, both general equilibrium model and partial equilibrium model have advantages and disadvantages. On the one hand, most CGE analyses have a high level of aggregation for sectors, in particular for non-energy sectors, ranging from several sectors to more than 20. As different energy-intensive sectors usually have substantial differences in competitiveness effects and their response to different competitiveness preservation and anti-leakage policy measures, such high aggregation of sectors fails to address sector-specific issues (Fischer and Fox, 2009). Partial equilibrium analysis, on the other hand, can fill the gap left by top-down macroeconomic models because they are based on more detailed data sets and include sector specific technological patterns or economic geography (Monjon and Quirion, 2010). On the other hand, because the interactions of sectors in the economy are not captured in a partial equilibrium analyses, it should be cautious in using the results on sectoral benefits from implementing anti-leakage measures to offset competitiveness loss in these sectors. In addition, an advantage of simplified partial equilibrium model is that, unlike in the complete CGE model, sensitivity analysis can be performed easily (Fischer and Fox, 2009).

Key messages

- There is disagreement among researchers both on the quantitative importance of leakage and on the effectiveness of the policy instruments proposed to limit leakage and competitiveness impacts. Though greatly influenced by model and parameter settings, the environmental and economic effectiveness of BAMs depend to a large extent on the coverage of participation countries and policy design, in particular the coverage of sectors, the application to all trade flows (imports and exports), and carbon intensity adopted (domestic intensity or origin country's intensity).
- Different studies showed different insights on the economic effectiveness of BTA measures. Most studies indicated that import levies are welfare improving for Annex B countries however for rebating, there is no agreement on its welfare effectiveness. For their competitiveness effects, BTAs may ameliorate the competitive loss to some extend and export rebates may be more effective. Import tariffs may only affects imports and export rebates may only affects exports. Therefore to address competitiveness concern effectively, policy combining both options might be necessary. In summary, from overall economic effectiveness point of view, the rebate policy buys Annex B countries more in terms of energy-intensive industries and employment, whereas the tariff policy buys them more in terms of welfare. In addition, since national circumstances differ across Annex B countries, different countries may have different preferences over candidate BAMs.
- Insights on the environmental effectiveness of BTAs in terms of reducing carbon leakage or global carbon emissions vary across economic analyses. Some studies indicated that BTAs may be effective in restoring the international competitiveness of carbon-intensive sectors in Annex B countries however their impacts on reducing global carbon leakage are limited. Other studies indicated that BTAs would be effective in reducing leakage of emissions, however leakage is very small even without the adjustments. These results suggest that BTAs may not be defended on an environmental ground of curtailing carbon leakage.

5. BTAs: WTO compatible?

Any BAM with a serious trade impact is likely to be challenged before the WTO. Given the vague nature of WTO law in this respect, the WTO may either uphold or strike down the BAM provision. In principle, a trade measure needs to be justified by the non-discrimination principle, i.e. national treatment and the most-favoured nation clauses, provided under GATT (Articles I, II, and III). Therefore, a climate change-related trade provision that applies only to imports is suspect to be protectionist. While a measure that applies to both imports and domestic products is accepted as long as it does not discriminate against imports from domestic products or against imports from particular countries. In addition, under trade law, price-based measures such as taxes are regarded as more transparent and economically more efficient than regulations. Hence, generally speaking, WTO rules push countries to adopt price-based measures such as tariffs or taxies, rather than quantitative import restrictions or trade restrictive regulations.

Depending on the form they take, trade measures to address competitiveness and carbon leakage concerns associated with the implementation of unilateral climate policy may be very different in both economic terms and legal terms. The choice of instrument is therefore crucial to their fate of WTO compatibility. As indicated by some legal analyses (e.g. Pauwelyn, 2007), an import restriction provision in the form of an import ban or punitive tariffs on imports from free-riding countries, anti-dumping duties against "environmental dumping", or counterveiling duties offset the "subsidy" of not imposing carbon restrictions would have little chance of survival before the WTO challenge. While border tax adjustment based on a domestic carbon tax or a cap-and-trade system would have better chance to survive WTO scrutiny.

Border tax adjustments on imported products

In its examination of BTAs, the 1970 GATT Working Party distinguished that taxes directly levied on products, the so-called indirect taxes (such as excise duties, sales taxes and the tax on value added), were eligible for adjustment, while certain taxes that were levied on producers, the so-called direct taxes (such as payroll, taxes on income, property and profits, social security charges, or interests), were normally not eligible for adjustment.

Pursuant to GATT Article II.2 (a)[1] allows WTO members to impose a charge equivalent to an internal tax on the importation of i) products that are like domestic products; or ii) articles from which the imported product has been manufactured or produced in whole or in part.

Based on these rules, however there is long-standing legal debate focusing on i) the eligibility of domestic carbon/energy taxes as indirect taxes for border adjustment; ii) the qualification of the allowance price under a cap-and trade system as an "internal tax"; and iii) the extent to which the energy inputs and fossil fuels could be considered to be articles from which the imported product has been manufactured or produced in whole or in part, related to the requirement of physically incorporated into the final product and the explanation of "direct" and "indirect" physical incorporation (Biermann and Brohm, 2005; Pauwelyn, 2007).

If the price-based climate policy takes the form of a carbon tax, it needs to pass two critical eligibility tests for being adjustable under GATT: (i) carbon/energy taxes are indirect taxes; and (ii) energy/carbon emissions are articles incorporated in whole or in part of imported product. On the one hand, following the definitions of "direct" versus "indirect" taxes in the WTO *Agreement on Subsidies and Countervailing Measures* (SCM), a carbon tax can be justified as an "indirect tax" and thus eligible for adjustment (Pauwelyn, 2007). On the other hand, it remains unclear whether input or process-related taxes on physical inputs (such as energy or carbon emissions), the so-called "taxes occultes", can be adjusted at the border. Therefore energy/carbon taxes can be defined as "indirect taxes" that are "indirectly" applied to products which lacks clear legal basis for justification (Biermann and Brohm, 2005).

If the climate policy takes the form of a cap-and-trade system, in general, its qualification for adjustment is more complicated than the policy designed in the form of a carbon tax. The fundamental concern is

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[1] "Nothing in this Article shall prevent any contracting party from imposing at any time on the importation of any product: (a) a charge equivalent to an internal tax imposed consistently with the provisions of paragraph 2 of Article III* in respect of the like domestic product or in respect of an article from which the imported product has been manufactured or produced in whole or in part."

whether the obligation to hold emission allowances can be qualified as an "internal tax or other internal charge of any kind". In addition, the complication is further under the situations: (i) when all or part of the allowances is allocated for free; and (ii) when the adjustment also takes the form, not of a tax, but of a requirement to importers to surrender emission allowances.

Even if border adjustment were permitted for a carbon tax or a cap-and-trade system, one more critical question is the definition of "likeness" of domestic and imported products in its relations to the non-discrimination principle. The WTO Appellate Body in the *EC-Asbestos* case provided four "characteristics" for assessing the "likeness" including: (i) the physical properties of the products; (ii) the extent to which the products are capable of serving the same or similar end-uses: (iii) the extent to which consumers perceive and treat the products as alternative means of performing particular functions in order to satisfy a particular want or demand; and (iv) the international classification of the products for tariff purposes. However whether steel from China made with coal (high carbon-intensity), for example, is "like" steel from US using natural gas (low carbon-intensity) may remain unclear.

Border tax adjustments on exported products

GATT (Article XVI on *Subsidies* and Ad Article XVI, 1994) and WTO SCM Annex I Item (g) permit, under certain conditions, the use of border tax adjustments on exported products. However, export BTAs cannot be subject to anti-dumping duties aimed at exports at less than domestic market price, nor to countervailing duties aimed at offsetting certain subsidies provided in the exporting country. In addition, the rebate should not be larger than the actual indirect tax levied on "like" products "when sold for domestic consumption".

GATT Article XX on the general exceptions clause

More related to climate change measures is GATT Article XX, which provides a number of specific exemptions from GATT rules, in particular related to the protection of human, animal and plant life or health (paragraph (b)) and the conservation of exhaustible natural resources (paragraph (g)). However, there are many debates on its application to climate-oriented trade measures. Several case laws (*US-Shrimp* case, *Brazil-Retreaded Tyres* case, *EC-Asbestos* case, etc.) indicated the importance for the trade measure at issue to show (i) the satisfaction in the requirements of the "chapeau"[2] of Article XX on the manner in which trade measures are applied; (ii) the necessity of the trade measure and the availability of alternative options in achieving the environmental objective related to Article XX (b) and (g); and (iii) substantial link between the trade measure and the stated climate change policy objective (means and ends relationship).

On the one hand, the opponent to the justifiability of BAMs by WTO law must prove that the policy is not worthy of an exception under Article XX and show that a less trade-restrictive policy option is available and effective (related to (ii)), or that the policy does not contribute toward achieving a reasonable climate goal at all (related to (iii)). In this regard, Manders and Veenendaal (2008) reveals that alternative measures, in particular recycling part of permit auction revenues to exposed ETS-sectors and greater reliance on the CDM, could be more effective than a border measure. In addition, several economic

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[2] "Subject to the requirement that such measures are not applied in a manner which would constitute a means of arbitrary or unjustifiable discrimination between countries where the same conditions prevail, or a disguised restriction on international trade…"

analyses (e.g. Babiker and Rutherford, 2005; Fischer and Fox, 2009) reveal that BAMs' contribution to the conservation of the climate is not assured. On the other hand, the proponent to a trade measure needs to demonstrate that it has been well tailored to achieve a legitimate environmental objective in a least trade restrictive manner. Protecting domestic producers from foreign competition may therefore not be recognized as a legitimate policy objective under WTO law (Houser, et al, 2008).

Practical challenges

Once border adjustments were permitted by the WTO, collecting the relevant data for the process-based calculation of a border adjustment, that is, tracing the proper amount of taxed input in the production process in the respective of country of origin is still difficult. There are several proposals to reducing complexity. One is to limit the number of products subject to BTA to a manageable level. As for exports, an energy-added tax method, similar to invoice methods for VAT can be used. In the case of imports where the necessary information on the production process is limited or not provided by the exporter, the use of a benchmark of "the best available technology" seems to be a feasible approach compatible with world trade law (Pauwelyn, 2007; Godard, 2007; Ismer and Neuhoff, 2004), however is weaker adjustment factor and would therefore be less effective (Takeda, 2010).

Another challenge is permit allocation. Auctioning may be a prerequisite for border adjustment, since the free allocation of permits through grandfathering might be an unfair subsidy (de Cendra, 2006; Hepburn et al., 2006; Pauwelyn, 2007).

Key messages

- On the one hand, WTO treaty law lacks clarity regarding the legality of border adjustments for energy/carbon taxes when goods are imported. The case law is not unambiguous as to whether such taxes could be supported through border adjustments.
- On the other hand, BTAs are not, as a matter of principle, ruled out by the pertinent rules of international trade law. Past case law even suggests that such measures could possibly be found admissible in a trade dispute. Even that a violation of free trade disciplines, such as the most-favored nation or national treatment principles, is found, the measure could possibly be justified under the general environmental exceptions of the General Agreement on Tariffs and Trade.
- To make it having more chances to be justifiable by WTO law, several points in designing the BAM are necessary to be considered. First and foremost, a trade measure should apply to both imports and domestic products and carbon price and should not discriminate against imports from domestic products or against imports from particular countries. Second, the policy objective of such trade measure should be positioned at anti-leakage rather than protecting from foreign competition. Third, it is necessary to demonstrate that a trade measure is necessary and there is substantial link between the trade measure and stated climate change policy objective. Forth, the border adjustment is better to take the form of a border tariff than a requirement to importers to surrender emission allowances. Fifth, the use of the benchmark of "the best available technology" as a method of calculating the carbon footprint of imports seems to be a feasible approach compatible with world trade law. Sixth, to limit the impact on trade, only a limited list of imports of energy-intensive raw materials should be covered. Finally, auctioning may be a prerequisite for border adjustment and any form of free allocation would increase the complexity and require a proportional adjustment on the tariff rate.

6. Conclusions

In this paper, we reviewed anti-leakage policy measures, in particular border adjustments, to address competitiveness and carbon leakage concerns in making domestic carbon pricing policy to achieve the reduction target. Several preliminary conclusions come out based on an extensive review of literature on quantitative analyses of competitiveness and carbon leakage impacts and the effectiveness of policy measures to address these concerns on the one hand, and debates on the political feasibility and WTO compatibility of border adjustment measures on the other hand.

First, carbon pricing achieved through a carbon tax or a cap-and-trade system is typically regarded as the most cost-effective means of meeting a given climate target for the economy as a whole. However its implementation could reduce the international competitiveness of key carbon-intensive, trade-exposed industries, and thus production and employment, if major trading partners do not implement. Along with competitiveness concern, carbon emissions increased in other countries without climate policies due to the implementation of carbon pricing policy, i.e. the carbon leakage issue, causes another concern over the effectiveness of unilateral climate policy.

Economic analyses indicated that the economy-wide competitiveness and carbon leakage impacts are limited. However for a few carbon-intensive, trade-exposed manufacturing industries, the leakage rate may be high and would form a real policy concern. In addition, many studies indicated that among three channels of carbon leakage the most important mechanism for leakage is through world energy markets, not trading in non-energy markets.

Second, where the competitiveness and carbon leakage are real policy concerns, the first best policy option to address them is the pursuit of a global international agreement that imposes a similar CO_2 price signal to all emitters. However, by envisaging the reality that to reach such a unanimous global agreement at present being difficult, domestic carbon pricing policy with anti-leakage provisions, in particular border adjustment measures to level the playing field would be one of the options, however would only be the second or third best option of international climate policy.

Many economic analyses reveal that most of border adjustment measures help protect international competitiveness at different degrees however either their effectiveness to reduce global emissions is limited or entail welfare losses. In addition, largest share of leakage may arise from the effects of climate policies on energy prices, adjustment policies can therefore only mitigate leakage on the margin but are quite limited in terms of reducing global emissions. For a wide range of BAM options, it is also difficult to rank order. The effectiveness depends on the relative emissions rates, elasticity of substitution, and consumption volumes. These results suggest that border adjustments may not be defended on an environmental ground of curtailing carbon leakage.

Third, besides the question whether the trade measures at issue can effectively deliver the expected economic and environmental benefits there are several cautions about their potential costs and risks. (i) Trade restrictions skew the optimal allocation of the world's resources and the principle of comparative advantage which in turn may impact adversely on countries which impose such trade measures. (ii) Competitiveness impact can be exaggerated and abused for purely trade protectionist purposes. (iii)

BAMs implemented unilaterally may undermine the trust necessary for future international cooperation and agreement on emission reduction. (iv) The implementation can be costly due to the difficulty in assessing product-based carbon footprint at individual country basis. (v) A BAM is likely to be challenged by WTO law and trigger a WTO complaint.

Forth, even if border adjustments are demonstrated to be economically efficient and designed so as to be compatible with WTO rules, however if pursued unilaterally, they risks repercussions for international cooperation on climate policy. Border adjustments can be implemented effectively only if they are pursued in an international context that ensures trust and shared understanding of the purpose of the measure and limits scale and scope to address leakage concerns clearly.

Fifth, many developing countries have already adopted a number of policies and measures, including ambitious targets for renewable energy, reductions in energy intensity, efficiency standards for vehicles, and reforestation and voluntary export taxes on carbon-intensive exports that could be equivalent to the carbon pricing policy implemented or to be implemented in Annex B countries. The implications of such new policy trend happening in developing countries on the size of carbon leakage and thus the effectiveness of border adjustments against their high economic and administration costs should be examined further.

Last but not least, whether border adjustment measures are necessary to addressing carbon leakage concern and how these measures are approached may have implications for the world’s progress on carbon pricing efforts. It will be important to ensure that approaches to tackling carbon leakage are not locked-in to the wrong path, but rather create incentives to move the world faster towards more effective global action.

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