ALTERNATIVE APPROACHES FOR LEVELLING CARBON PRICES IN A WORLD WITH FRAGMENTED CARBON MARKETS

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Abstract: When carbon markets are fragmented and carbon prices vary across regions, concerns arise that acting countries may encounter competitiveness and welfare losses and changes in production may lead to carbon leakage. Border carbon adjustments (BCAs) have been proposed as a response measure to address these issues. However, more cooperative response policies, such as linking carbon markets, can also reduce the burden of emissions reduction in acting countries and help level carbon prices. This paper analyses the effects of BCAs and both direct and indirect linking on welfare, competitiveness and carbon leakage within a global recursive-dynamic computable general equilibrium (CGE) model. Results illustrate that a uneven carbon pricing can indeed lead to substantial competitiveness and welfare losses for acting countries as well as to carbon leakage. Of the instruments investigated in this paper, BCAs appear to be the best measure to preserve the competitiveness of acting countries as they shift part of the burden of emission reductions to non-acting countries. While BCAs are effective for acting countries, they cause severe welfare and competitiveness losses for non-acting countries. As a result, BCAs are less effective than linking in reducing global welfare losses, as linking tends to be beneficial for both acting and non-acting countries. The advantages of BCAs diminish as the carbon market is extended to more emission sources or to a wider international participation.

Keywords: climate mitigation policy, competitiveness, carbon leakage, general equilibrium

JEL codes: Q43, Q54, H2, D61

Disclaimer

The views expressed in this paper are those of the authors and do not necessarily represent the views of the OECD or of its member countries.

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1. Introduction

Climate change is a global problem that calls for global policy action. In recent years, the participation of countries has been increasing but policy action is proceeding only gradually. Partly reflecting strong free-riding incentives, the immediate prospects for globally harmonised carbon markets addressing the negative externality associated with greenhouse gas (GHG) emissions are weak. The Conferences of Parties (COPs) held in Copenhagen in 2009, Cancun in 2010 and Durban in 2011 suggested that international climate policy action will likely be built out of a collection of fragmented domestic actions, rather than being globally coordinated. Many countries are worried that strong unilateral reductions could foster “carbon leakage”, lead to domestic welfare losses and undermine the international competitiveness of domestic industries. Concerns are particularly focused on *Emission-Intensive & Trade-exposed* (EIT) sectors (see details in Table 1). These sectors are likely to encounter the largest trade and output losses, as their high emission intensity implies increased production costs and their trade exposure implies limited options for passing on the costs of pricing carbon.

To address these issues, a number of business leaders and politicians advocate the use of Border Carbon Adjustments (BCAs). BCAs are import fees and/or export subsidies levied by countries imposing a climate policy on goods manufactured in countries that are not imposing any climate policy. BCAs, similarly to environmental tax rebates, are considered to be a measure to “level the playing field” (see Burniaux, *et al.*, 2012, Bernard *et al.*, 2007; Fischer and Fox, 2009). BCAs can diminish the uneven producers’ condition created by regional differences in climate policies. In the European Union (EU), BCAs have recently been contemplated in the political debate, and in the United States (US) they featured as a potential measure in two legislative initiatives put to Congress in 2009. EIT sectors have been the main focus of BCA proposals. BCAs can contribute to reduce competitiveness and output losses in domestic EIT sectors through levelling domestic and imported prices (Babiker, 2005; Demailly and Quirion, 2006). The environmental rationale for BCAs is that they would reduce carbon leakage.

The economic effects of BCAs are a priori ambiguous. On the one hand, like any tariff, BCAs increase consumer prices, resulting in a welfare loss. On the other hand, unilaterally implementing a carbon tax already distorts domestic resource allocation; imposing BCAs may in part correct this distortion if they at least partly restore the initial (pre-carbon tax) resource allocation. Another potential source of welfare gain is that BCAs can improve domestic terms of trade if they are imposed by a large economic area. Previous analyses show that BCAs are not generally sufficient to countervail the large output losses in EIT sectors in acting countries and would cause welfare losses in non-acting countries (Burniaux *et al.*, 2012; Mattoo *et al.*, 2009, Winchester *et al.*, 2011). The political economy implications of welfare losses in non-acting countries are not well understood: they could lead to “trade wars”, or, on the other hand, create an incentive for non-acting countries to price carbon.

The purpose of this paper is to analyse whether more cooperative policy actions than BCAs, considered as both import fees and export subsidies levied by acting countries on non-acting countries, could deal more effectively with the issues of competiveness losses and carbon leakage rising in a fragmented carbon market world. More specifically, the analysis considers alternative market mechanisms oriented towards levelling carbon prices across countries through linking carbon markets. Linking can reduce carbon leakage as well as output and competitiveness losses, as it balances the domestic reduction requirements and smoothes distortions across countries (Jaffe and Stavins, 2007). The paper considers direct linking as well as ‘indirect’ linking. The direct linking instrument considered is the implementation of unlimited permit trading between all acting countries (OECD, 2009). The possibility to use a common pool of carbon offsets is considered as 'indirect' linking (Dellink *et al.*, 2010). As in the case of Clean Development Mechanism (CDM), offsets enable emission reduction commitments in acting countries to be met by undertaking emission reductions in other geographical areas and lead to a (partial) harmonisation of carbon prices across the acting countries.

To compare these policy measures, the analysis relies on a benchmark policy scenario based on a fragmented carbon markets hypothesis and restricted to limited emissions sources. In this scenario only Annex I countries are acting and emissions of non-CO_2 greenhouses gases as well as all emissions from agriculture (and LULUCF) and households are exempted from carbon pricing. The analysis focuses on comparing policy instruments in their effectiveness to (1) preserve welfare levels (i.e. their cost-effectiveness) both in acting and non-acting countries; (2) correct the negative impacts of asymmetric carbon pricing on international competiveness of acting countries, and (3) reduce the presence of carbon leakage. Output and trade flows are used as key indicators to study international competiveness. To compare welfare impacts of the policies, the benefits of the policies are kept constant throughout all policy simulations by fixing global emissions. As the corrective policies considered here are all distortive per se and are implemented in a 'distortive world', their welfare and output effects are a priori ambiguous and are therefore largely an empirical matter. To give quantitative answers about the sign and magnitude of the economic effects of these corrective instruments, an applied global Computable General Equilibrium (CGE) framework is an appropriate analytical tool. The analysis is based on the ENV-Linkages model, a global CGE model, featuring recursive dynamics and capital vintages (Chateau *et al.*, 2012).

The results of the policy simulations show that a fragmented climate policy can lead to competitiveness and welfare losses for acting countries as well as to carbon leakage. BCAs and linking can be used as response measures to address these issues. BCAs are more effective in restoring competitiveness in acting countries than linking, as they shift the burden of emission reductions to non-acting countries. While BCAs are effective for acting countries, they cause output, trade and welfare losses in non-acting countries. As a result, BCAs are less effective than linking in preserving global welfare. A sensitivity analysis on the design of the BCAs shows that when only import tariffs are implemented, instead of both import tariffs and export subsidies, BCAs become less effective in re-establishing initial output levels. A sensitivity analysis on the characteristics of the climate policy design shows that extending carbon markets to more emission sources or widening the participation of countries to the climate policy increases the effectiveness of linking compared to BCAs. This confirms the general insight that best solution to deal with leakage and competitiveness issues is a global carbon market that prices all sources of carbon, regardless of the sector, region or gas (cf. OECD, 2009).

The remainder of the paper is structured as follows. Section 2 presents an overview of the modelling framework used for the analysis, Section 3 describes the policy scenarios and how these have been implemented in the model. Section 4 presents the main results and Section 5 performs sensitivity analysis of the main results to the size of the coalition of acting countries, the emissions sources included and the design of BCAs. Section 6 concludes.

2. Model and data

2.1. An overview of the ENV-Linkages Model

The analysis is based on ENV-Linkages, a global recursive-dynamic neo-classical CGE model (Chateau *et al*, 2012). ENV-Linkages, as a successor of the OECD GREEN model (Burrniaux et al., 1992), shares its basic structure with e.g. ENVISAGE (Mattoo *et al.*, 2009) and MIT-EPPA (Winchester *et al.*,

2011) models, featuring recursive dynamics and capital vintages. A more comprehensive model description is given in Chateau *et al.* (2012).

Production in ENV-Linkages is assumed to operate under cost minimisation with perfect markets and constant return to scale technology. The production technology is specified as nested Constant Elasticity of Substitution (CES) production functions in a branching hierarchy (cf. Figure A.1 in Annex A). This structure is replicated for each output, while the parameterisation of the CES functions may differ across sectors. The nesting of the production function for the agricultural sectors is further re-arranged to reflect substitution between intensification (e.g. more fertiliser use) and extensification (more land use) of activities; or between intensive and extensive livestock production. The structure of electricity production assumes that a representative electricity producer maximizes its profit by using the different available technologies to generate electricity using a CES specification with a large degree of substitution. Non-fossil electricity technologies have a structure similar to the other sectors, except for a top nesting combining a sector-specific natural resource with all other inputs. This specification acts as a capacity constraint on the supply of these electricity technologies. The model adopts a putty/semi-putty technology specification, where substitution possibilities among factors are assumed to be higher with new vintage capital than with old vintage capital. This implies relatively smooth adjustment of quantities to price changes. Capital accumulation is modelled as in the traditional Solow/Swan neo-classical growth model.

The energy bundle is of particular interest for analysis of climate change issues. Energy is a composite of fossil fuels and electricity. In turn, fossil fuel is a composite of coal and a bundle of "other fossil fuels". At the lowest nest, the composite "other fossil fuels" commodity consists of crude oil, refined oil products and natural gas. The value of the substitution elasticities are chosen as to imply a higher degree of substitution among the other fuels than with electricity and coal.

Household consumption demand is the result of static maximization behaviour which is formally implemented as an "Extended Linear Expenditure System". A representative consumer in each region – who takes prices as given – optimally allocates disposal income among the full set of consumption commodities and savings. Saving is considered as a standard good in the utility function and does not rely on forward-looking behaviour by the consumer. The government in each region collects various kinds of taxes in order to finance government expenditures. Assuming fixed public savings (or deficits), the government budget is balanced through the adjustment of the income tax on consumer income. In each period, investment net-of-economic depreciation is equal to the sum of government savings, consumer savings and net capital flows from abroad.

International trade is based on a set of regional bilateral flows. The model adopts the Armington specification, assuming that domestic and imported products are not perfectly substitutable. Moreover, total imports are also imperfectly substitutable between regions of origin. Allocation of trade between partners then responds to relative prices at the equilibrium. Market goods equilibria imply that, on the one side, the total production of any good or service is equal to the demand addressed to domestic producers plus exports; and, on the other side, the total demand is allocated between the demands (both final and intermediary) addressed to domestic producers and the import demand.

CO_2 emissions from combustion of energy are directly linked to the use of different fuels in production. Other GHG emissions are linked to output in a way similar to Hyman *et al.* (2002). The following non-CO_2 emission sources are considered: *i)* methane from rice cultivation, livestock production (enteric fermentation and manure management), fugitive methane emissions from coal mining, crude oil extraction, natural gas and services (landfills and water sewage); *ii)* nitrous oxide from crops (nitrogenous fertilizers), livestock (manure management), chemicals (non-combustion industrial processes) and services (landfills); *iii)* industrial gases (SF6, PFC's and HFC's) from chemicals industry (foams, adipic acid, solvents), aluminium, magnesium and semi-conductors production.

ENV-Linkages is fully homogeneous in prices and only relative prices matter. All prices are expressed relative to the *numéraire* of the price system that is arbitrarily chosen as the index of OECD manufacturing exports prices. Each region runs a current account balance, which is fixed in terms of the *numéraire*. As a consequence, real exchange rates are immediately adjusted to restore current account balance when countries start exporting/importing emission permits.

2.2. Data and calibration of the baseline scenario

The version of the model used here represents the world economy in 17 countries/regions, each with 27 economic sectors, as illustrated in Table 1. These include five electric generation sectors, five agriculture-related sectors (including fishing and forestry), five energy-intensive industries, three fossil fuel extraction sectors, transport, refineries and distribution of petroleum products, services, construction and four other manufacturing sectors. The core of the static 2004 starting year equilibrium is formed by a set of Social Account Matrices (SAMs) that describe how economic sectors are linked; these are based on the GTAP 7 database (Narayanan and Walmsley, 2008). Many key parameters of the model are set on the basis of information drawn from various empirical studies and data sources (details given in Burniaux and Chateau, 2008).

Table 1. ENV-Linkages model sectors and regions

Commodities	***Countries and regions***
Energy	*Annex I regions*
Coal	Europe – EU-27 plus EFTA (EUR)
Crude oil	United States of America (USA)
Gas	Japan (JPN)
Refined oil products	Canada (CAN)
Electricity*	Australia and New Zealand (ANZ)
	Russia (RUS)
Emission-intensive & trade-exposed sectors	Other European Annex I countries (RA1)
Chemicals	
Non-metallic minerals	*Non-Annex1 regions*
Iron and steel industry	Other Energy Exporting countries, Middle-East and North Africa (EEX)
Non-ferrous metals	Brazil (BRA)
	Mexico (MEX)
Forestry, agriculture and fisheries	China (CHN)
Rice	India (IND)
Other crops	Indonesia (IDN)
Livestock	Korea (KOR)
Forestry	Mexico (MEX)
Fishery	Other middle income countries (MIC)
	Other low income countries (LIC)
Other industries and services	
Transport services	
Paper–pulp–print	
Fabricated Metal Products	
Other Manufacturing	
Services	
Construction & Dwellings	
Other Mining	
Food Products	

* Electricity is split into 5 sectors: nuclear power, solar and wind electricity, renewable combustibles and waste electricity, fossil fuel based electricity, and hydro and geothermal electricity.

The baseline scenario projects future emissions assuming no new climate policies are implemented, thus providing a benchmark for climate policy scenarios. Projections are based on assumptions on the long-term evolution of output growth, relative prices of fossil fuels, and potential gains in energy efficiency. The construction of the economic baseline scenario is described in detail in the *OECD Environmental Outlook to 2050* (OECD, 2012) and in Chateau *et al.* (2011). The baseline scenario is built on various exogenous trends: employment levels derived from labour force projections and from estimates of national unemployment rates provided by the OECD; labour productivity projections, based on a conditional-convergence hypothesis (for details see Duval and de la Maisonneuve, 2010); autonomous energy efficiency factors and fossil-fuel production calibrated on IEA World Energy Outlook projections (IEA, 2010a and 2010b), and emissions of non-CO2 fossil-fuel combustion greenhouse gases calibrated to match US-EPA projections (2005). Moreover, the baseline has been adjusted to incorporate the effects of the economic crisis of 2008-2009 using medium-term projections made by the World Bank (2011), IMF (2011) and OECD (2011). For this paper all values are expressed in 2004 USD.[1]

3. Scenarios

The assessment of the economic effects of BCAs relies first on a benchmark climate policy scenario. This reference policy scenario (*Frag*) is based on a fragmented carbon markets hypothesis and starts from the premise that it may not be realistic to expect large emission reductions in the coming decade. The *Frag* scenario does not consider countervailing policies to address leakage and competitiveness issues. The regional emission reduction targets implemented in the *Frag* policy scenario are based on an assessment of the pledges made in the Annex to the Copenhagen Accord (FCCC/SB/2011/INF.1/Rev.1; see Dellink *et al.*, 2010, and OECD, 2012 for more details on the interpretation of these targets), with the assumption that (i) the lower end of the pledges will be implemented (as the upper end pledges are normally conditional upon stringent international action and thus not in line with the hypothetical fragmented world represented by this scenario); (ii) land use (LULUCF) credits will not be used (as land use emissions are excluded from the analysis); (iii) surplus allowances from the first commitment period of the Kyoto Protocol are not used.

The required emission reductions assumed in the *Frag* policy scenario and their interpretation in the modelling framework are summarised in Table 2; they are expressed as reductions from 1990 emission levels, as in the submissions to the UNFCCC. While non-Annex I countries have also provided pledges for mitigation action (see FCCC/AWGLA/2011/INF.1), in this hypothetical scenario only Annex I countries are acting and non-Annex I countries do not undertake any carbon pricing policy. This assumption allows full focus on the competitiveness impacts of a truly fragmented carbon market, not to accurately reflect intended policies or international climate negotiations.

The targets are defined at the country level for the emissions of the Kyoto basket of greenhouse gases (excl. LULUCF emissions, and expressed in CO_2-eq).[2] Not much information is provided on how the required reductions are allocated across different emission sources (e.g. which sectors are included). The fragmented policy scenario considers that not all sources of emissions are subject to a carbon price and that the same required economy-wide overall GHG mitigation efforts will need to be achieved in targeted sectors only. The reference mitigation instrument is a domestic Emission Trading Scheme (ETS) on CO_2 emissions from fossil fuel combustion, where the government auctions the permits (but permits are not internationally tradable); proceeds from this auctioning are fully redistributed to households in a lumpsum fashion. Emissions of non-CO_2 greenhouses gases as well as all emissions from agriculture (and

[1] Key indicators are 2012 are presented in Table A.1 in Annex A.

[2] The conversion factors used are taken from the IPCC Fourth Assessment Report (Working Group I Report "The Physical Science Basis", 2007, available at: http://www.ipcc.ch/ipccreports/ar4-wg1.htm).

LULUCF), and households are assumed to be exempted from carbon pricing. In other words, targets are defined on domestic emissions in CO_2-eq and converted into a CO_2 emissions target for the selected sectors while ensuring that the overall reduction level is identical across scenarios. The fragmented policy scenario also assumes that the various domestic carbon markets are not linked (except between the EU and EFTA, and between Australia and New Zealand) and carbon offsets cannot be used.

Table 2. Mitigation efforts in the fragmented policy scenario (*Frag*)

Region	Policy description	Scenario target (GHG emission change)
Europe – EU-27 plus EFTA (EUR)	EU27, Liechtenstein and Switzerland -20% from 1990; Norway -30% from 1990; Iceland and Monaco -30% from 1990	-20% from 1990
United States of America (USA)	-17% from 2005	-3.5% from 1990
Japan (JPN)	-25% from 1990	-25% from 1990
Canada (CAN)	-17% from 2005	+2.5% from 1990
Australia and New Zealand (ANZ)	Australia -5% from 2000; New Zealand -10% from 1990	-12% from 1990
Russia (RUS)	-15% from 1990	-15% from 1990
Other European Annex I countries (RA1)	Ukraine -20% from 1990; Belarus -5% from 1990; Croatia -5% from 1990; emissions for other countries in this group without a pledge (incl. Turkey) are assumed to remain at BAU level	-19% from 1990

Given the effects that such a fragmented carbon policy is expected to have on acting countries, different response policies are considered. To be able to compare the welfare impacts across policy simulations, global GHG emissions are maintained equal to those in the *Frag* policy scenario.[3] Consequently, climate impacts and thus the benefits of the policies, which are not included in the modelling framework, are constant.

The first response policy considered is the use of BCAs (*BCAs scenario*). There are different way to design BTAs, as described in Monjon and Quirion (2010). In this paper BCAs are modelled as carbon-based import tariffs calculated on direct and indirect (electricity-only) CO_2 content of goods produced by non-acting countries, combined with domestic carbon-based export-subsidy support for acting countries. These BCAs measures aim at levelling carbon prices across acting and non-acting countries, by correcting (i) the import prices of goods that are not subject to domestic carbon pricing and (ii) the export prices of domestically produced goods, to restore their competiveness both on domestic and foreign markets. For symmetry, only priced sources of carbon are subject to border adjustments (not agricultural goods for example). The carbon content of goods is updated each simulation year in order to take into account structural changes in the production processes in non-acting countries.

The second response policy considers a direct linking (*Link scenario*) between domestic ETS of acting countries. In this case, regulated entities can sell/buy emission allowances to/from another ETS to meet their domestic compliance obligations. From a theoretical perspective, in a first-best world where the carbon price is the only source of distortion, linking ETSs directly lowers the overall cost of meeting their joint targets by allowing higher-cost emission reductions in one ETS to be replaced by lower-cost emission reductions in the other (OECD, 2009). This leads to harmonisation of carbon prices among the linked

[3] With constant global emissions across simulations, the required emissions reduction of acting countries may change in different simulations. For instance, with BCAs emissions in non-acting countries are generally reduced, therefore diminishing the required efforts of acting countries. In such cases, to remain coherent with the set targets, all changes to emissions reduction are split across acting regions proportionally to the set targets.

systems. The allocation of allowances across participating countries corresponds to the domestic targets defined in the *Frag* scenario.

The third response policy is 'indirect' linking in the form of the use of offsets (*Offsets scenario*). As in the case of the Clean Development Mechanism (CDM), offsets allow emission reduction projects in certain non-Annex I countries. In this case, credits are purchased by (regulated entities in) acting countries to meet part of their emission reduction commitments. Crediting mechanisms indirectly link the ETSs of countries covered by binding emission caps because credits are accepted in several different ETSs. Indeed, they result in partial levelling of carbon prices across the different ETSs when the same offset credits are allowed in different ETSs. In principle, well-functioning crediting mechanisms could improve the cost-effectiveness of GHG mitigation policies in developed countries and reduce carbon leakage and competitiveness concerns by partially harmonising the carbon price (OECD, 2009). Only sectors in non-acting countries that are covered by ETS in acting countries are considered as eligible sources for offsets. As in OECD (2012) a cap on offsets allowed in acting countries is assumed to be equal to 20% of the emissions reduction in the *Frag* scenario.[4] This assumption avoids the outcome of all emission reductions being made in non-acting countries where the abatement costs are lower.

The analysis compares each policy response applied individually as well as a combination of the two types of linking (*Offsets_Link*), of BCAs with direct linking (*Link_BCAs*) and indirect linking (*Offsets_BCAs*) and of all options together (*All*). Studying these combinations will show whether there is still a case for BCAs in presence of linking. Table 3 summarises the scenarios considered in the analysis. All policy scenarios consider policies implemented starting in 2013 and until 2020. Results are analysed for the year 2020 either as values or as percentage changes with respect to the baseline scenario.

Table 3. Policy scenarios

Scenario	**Description**
Reference policy	
Frag	Simple implementation of a carbon policy by each acting country individually
Single-instrument response policies	
BCAs	Carbon-based tariffs and export tariffs are levied on non-acting countries
Link	The acting regions are linked though an international carbon market
Offsets	Acting countries are allowed to implement emissions reduction projects in non-Annex I countries with no emissions constraints
Multiple-instrument response policies	
Offsets_Link	Offsets and linking
Offsets_BCAs	Offsets and BCAs
Link_BCAs	Linking and BCAs
All	Linking, offsets and BCAs

[4] The choice of a 'baseline' against which offset credits are granted have an impact on the volume of credits generated and matters for carbon leakage. As in OECD (2009) a sector-wide offset mechanism simulated where the reference emission level is set as the emission level in offset host countries when Annex I countries are acting (the Frag scenario). Technically offset credits are modelled for host countries as an output-based rebate together with a domestic carbon tax. Host countries compete for providing offset credits to ensure the least-cost options are taken. More information is provided in Chateau et al. (2012)

4. Results

4.1. Economic impacts in the fragmented scenario case

The *Frag* reference policy scenario has economic and competitiveness effects in the acting countries, as well as in non-acting countries. Results for key indicators are illustrated in Table 4 for the year 2020 as percentage change with respect to the baseline scenario. Welfare decreases in acting countries as a consequence of the additional costs of reducing emissions, with the exception of the Other European Annex I countries where welfare slightly increases due to an improvement in their terms of trade.[5] These mitigation efforts also have indirect effects; not least through the international fossil fuel markets, where there is a downward pressure on prices (and hence income for fossil fuel exporters) resulting from the reduced demand for energy in acting countries. EIT sectors are particularly affected, with a negative impact on both output and exports. These effects are highest for Canada, the Australia & New Zealand region and Japan, and are relatively small in EU & EFTA and in the USA. In general, these losses are a compound result of changes in competitive position with respect to the main trading partners and domestic demand changes. In Australia & New Zealand, the international aspect is dominant: EIT export losses are larger than production losses. Especially for Canada and Japan a main driver of the EIT output loss is the relatively high carbon price.

The carbon price, which is region-specific as in this scenario all regions act individually, is highest in Japan (126 USD per ton of CO_2), followed by Canada (95 USD per ton of CO_2). Australia & New Zealand, EU & EFTA and the US have similar prices, ranging from 54 to 60 USD per ton of CO_2 eq. Finally, the price in the Other European Annex I countries is very low (1 USD per ton of CO_2) due to the low stringency of the emission target, while for Russia the emission target is above the baseline emission projection and thus no efforts are needed to reach the target. This situation is caused at least partially by the reduction in economic activity and emissions after the collapse of the Soviet Union.

The climate policies implemented in the acting countries also indirectly affect non-acting countries. Interestingly, the effect on welfare in non-acting countries is negative and larger than in acting countries. The negative effect on welfare is for all non-acting regions, except South Africa. The effect is stronger in the case of energy exporting economies, where the reduced energy demand in acting regions leads to a decrease in income from exporting fossil fuels. This is also due to the lower fossil fuel prices, which reduce the revenues from exported energy for non-acting countries.[6] Benefiting from the fall in output of energy intensive products in acting countries, production and exports in EIT sectors rise in non-acting countries, especially in Energy exporting countries, Korea and Indonesia. This also leads to an increase in emissions in most non-acting countries, causing carbon leakage.[7] The leakage rate from acting to non-acting countries is 8.6% for CO_2 and 4.3% for all GHGs (see Figure 2). The CO_2 leakage rate is higher as CO_2 emissions are linked to more trade exposed activities and are also the only emissions covered in the policy design.

[5] Regional welfare effects are aggregated using income shares.

[6] Oil prices in the various scenarios, as indexed to the baseline scenario, are illustrated in Annex A.

[7] The leakage rate is conventionally defined as the ratio between the emission increases in non-regulated countries over the emission reduction in regulated countries.

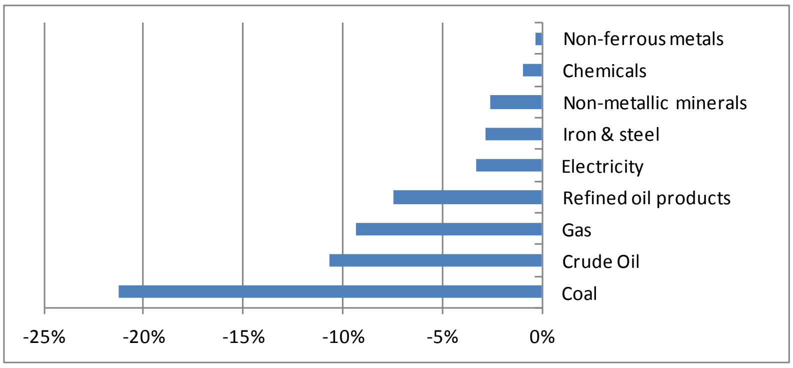
Table 4. Impacts of the fragmented policy scenario on key indicators in 2020 (% change wrt baseline)

Region	Welfare	Output (EIT sectors)	Exports (EIT goods)	GHG emissions	Carbon Price
Australia & New Zealand	-0.89	-8.9	-17.3	-16.5	58
Canada	-1.43	-10.2	-12.9	-21.3	94
EU & EFTA	-0.20	-1.3	-1.3	-9.4	54
Japan	-0.39	-5.7	-10.4	-18.6	126
Other European Annex I countries	0.14	2.1	2.7	-0.5	1
Russia	-1.15	4.9	8.4	0.0	0
USA	-0.31	-3.3	-5.3	-13.9	60
Acting countries	***-0.35***	***-2.7***	***-3.1***	***-10.7***	***72****
Brazil	-0.18	1.8	4.8	0.4	
China	-0.25	0.9	4.1	0.3	
Energy exporting countries	-1.34	3.4	4.7	-0.2	
Indonesia	-0.48	2.7	4.8	0.2	
India	-0.06	1.6	3.2	0.4	
Korea	-0.05	2.5	2.4	0.9	
Mexico	-0.26	1.9	5.6	0.6	
South Africa	0.03	2.0	4.9	1.1	
Other high and middle income countries	-0.32	2.6	3.0	0.2	
Other low income countries	-0.26	2.4	5.2	0.0	
Non-acting countries	***-0.45***	***1.5***	***3.9***	***0.3***	
World	***-0.38***	***-0.4***	***-0.5***	***-3.8***	

*This is an average CO_2 price calculated as a weighted average on covered emissions reductions.

Table 4 provides an aggregated view of competitiveness impacts, focusing on changes in output and exports by region. However, the impacts vary substantially across EIT sectors. Sectors with high energy intensity and limited opportunities to pass on additional costs due to trade exposure are most affected. The more homogeneous the produced commodity is, the more production patterns will change geographically. While the CGE modelling framework cannot capture the full details of the output effects at the sub-sectoral level, Figure 1 shows the degree to which output losses are concentrated in a few sectors.

Figure 1. Impacts of the fragmented policy scenario on EIT and energy sectors' output in acting countries in 2020 (% change wrt baseline)



4.2. Comparing response policies in addressing competitiveness issues

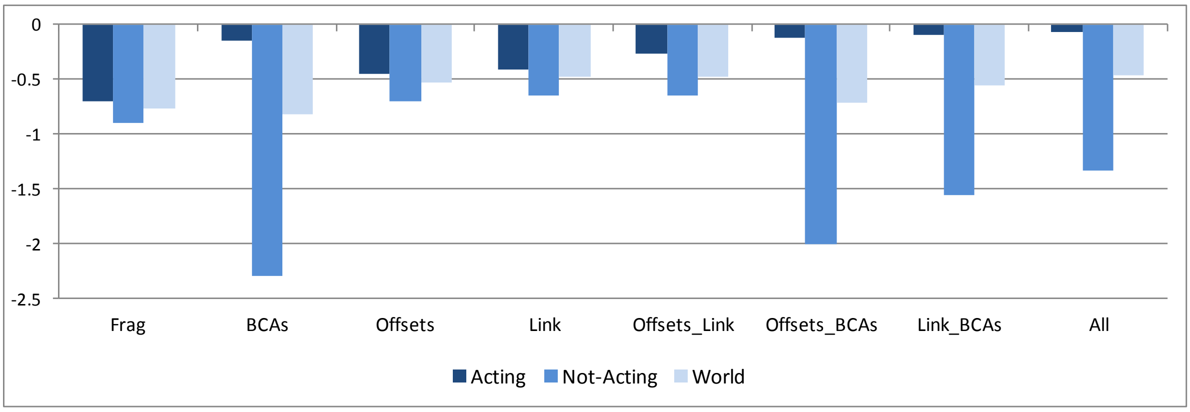
There are clear issues of competitiveness and carbon leakage for acting countries, which also have an impact on non-acting countries. The fragmented climate policy affects trade patterns of EIT sectors as well as welfare. Both acting and non-acting countries encounter a welfare loss. Although all non-acting countries encounter a welfare loss, this is particularly large for fossil fuel exporting countries. Acting countries could respond by applying BCAs or linking instruments to diminish the economic losses from the climate policy. This section compares the different response policies in their effectiveness to reduce competitiveness and welfare losses. While results are presented mostly looking at acting and non-acting countries in aggregate, tables in Annex B illustrate results by region for key indicators.

Figure 2 illustrates the impacts of the response policies on welfare compared to the baseline projection. When acting countries apply BCAs, they can almost re-establish their baseline welfare levels, although welfare is lower than in the baseline case in all cases with BCAs. Following the assumption that acting countries aim at achieving the same global emission reductions across scenarios,[8] when they apply BCAs or use offsets emissions will be reduced in non-acting countries and thus their domestic mitigation efforts will be smaller. However, welfare decreases for non-acting countries as they are now confronted with carbon pricing in their exporting sectors. Welfare at the world level is slightly worsened by the implementation of BCAs.

In the case of linking, welfare is improved for both acting and non-acting countries. Direct linking is slightly superior to indirect linking in improving welfare impacts, especially in acting countries, although this result depends on the level of offsets allowed in the *Offsets* scenario, which in this analysis is set to 20%. When both types of linking are implemented there are further benefits especially for acting countries.

Implementing linking and/or offsets together with BCAs reduces welfare losses in acting countries even further. Thus, for acting countries, even with linking and/or offsets, there is room for implementing BCA measures to reduce welfare losses. While direct linking can reduce global welfare losses when combined with BCAs, the global benefits from offsets when combined with BCAs are smaller. This is due to the welfare losses in non-acting countries caused by the reduction of their exports which follows the imposition of BCAs.

Figure 2. Welfare impacts of response policies in 2020 (% change wrt baseline)



Concerns for acting countries are particularly focused on EIT sectors as these suffer the highest output, trade and output losses, as illustrated in Table 5. In the *Frag* scenario acting countries face a 2.7% output loss, while their exports decrease slightly more. Imports of EIT goods slightly increase to compensate the production loss. At the same time, EIT sectors in non-acting countries benefit in aggregate from the competitiveness loss of acting countries. Output and exports increase in non-acting countries, while their imports decrease due to the loss in production in acting countries and to the increase in

[8] This assumption will be investigated in the sensitivity analysis.

domestic production. Global production and trade contract, as producers and consumers substitute from using EIT commodities towards cleaner goods and services.

BCAs appear to be the most effective instrument in re-establishing the initial output levels of EIT sectors in acting countries. Linking instruments also reduce the competitiveness losses by avoiding the most costly domestic mitigation measures to be taken and thus lowering mitigation costs in domestic EIT sectors, but to a much lower extent. While EIT sectors in non-acting countries benefit from the fragmented climate policy, they are negatively affected by the implementation of BCAs. The reduction of output in non-acting countries becomes larger than in acting counties in the presence of BCAs. This effect on output is also due to the high carbon intensity of many non-acting countries.[9] The positive effects of the fragmented climate policy on EIT sectors in non-acting countries persist in the case of linking, although the output gains are lower as the competitive position of EIT sectors in acting countries is partially conserved.

While all climate policies have a negative impact on global output, there is a strong difference in the regional distribution of cost across the scenarios. In the presence of BCAs both acting and non-acting countries face small output losses, while in the absence of BCAs, acting countries encounter output losses and non-acting countries increase their output though not sufficiently to maintain world output unchanged. As the instruments are complementary in shifting the burden to non-acting countries and diminishing costs between acting countries with linking, the combination of the various policy instruments leads to the smallest output losses.

Table 5. Competitiveness impacts of response policies in EIT sectors in 2020 (% change wrt baseline)*

	Output (EIT sectors)			Exports (EIT goods)			Imports (EIT goods)		
Scenario	**Acting**	**Non-Acting**	**World**	**Acting**	**Non-Acting**	**World**	**Acting**	**Non-Acting**	**World**
Frag	-2.7	1.5	-0.4	-3.1	3.9	-0.5	0.5	-1.8	-0.5
BCAs	-0.5	-0.6	-0.5	-0.9	-3.9	-2.0	-2.6	-1.3	-2.1
Offsets	-1.9	0.9	-0.3	-2.1	2.5	-0.4	0.2	-1.2	-0.4
Link	-1.9	1.0	-0.3	-2.4	2.8	-0.5	0.2	-1.4	-0.5
Offsets_Link	-1.4	0.6	-0.2	-1.7	1.9	-0.4	0.1	-1.0	-0.4
Offsets_BCAs	-0.5	-0.5	-0.5	-0.9	-3.3	-1.8	-2.3	-1.2	-1.9
Link_BCAs	-0.4	-0.4	-0.4	-0.5	-2.5	-1.3	-1.8	-0.7	-1.3
All	-0.3	-0.4	-0.3	-0.5	-2.1	-1.1	-1.5	-0.6	-1.1

* Here as in the rest of the paper output is expressed in real value at 2004 USD prices; exports in real value at 2004 FOB prices and imports in real value at 2004 CIF prices

By changing production patterns, the fragmented climate policy also affects the distribution of emissions across countries. In particular, emissions decrease in acting countries and increase in non-acting countries with respect to the baseline scenario, leading to carbon leakage. Carbon leakage, as presented in Figure 3, is considered as international leakage, namely changes in emissions in non-acting countries with respect to the emission reduction in acting countries. Further, the carbon leakage effect is decomposed in leakage within covered sectors (*Covered*), in non-covered sectors (*Other_Sector*), and in GHG other than CO_2, which is the only gas covered in this analysis (*Other_Source*).

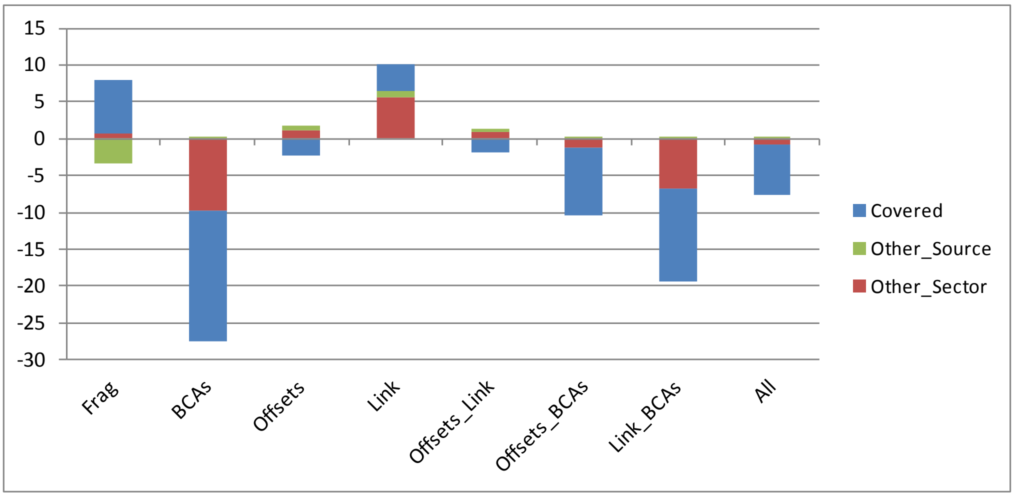
The leakage effect changes when response policies are implemented. BCAs can re-establish production patterns and not only eliminate the carbon leakage effect but even lead to a negative leakage

[9] Carbon intensities of GDP are presented in Table A.1 in Annex A.

rate. This happens when emissions are reduced not only in acting but also in non-acting countries.[10] For offsets, leakage rates are negligible even though non-acting countries have no domestic policy targets, as the opportunity to contribute to the offset markets implies that emissions are controlled in offset host countries.[11] Carbon leakage persists, albeit at a somewhat smaller level, if only direct linking is implemented, as emissions are reduced only in acting countries and no policy is implemented that has a direct impact on production or emissions of non-acting countries. In this case, the only leakage reduction comes from the harmonisation of carbon prices in acting countries, partially preserving the competitive position of their domestic EIT sectors. In the case of offsets, the small negative leakage rates reflect the emission reductions in non-Annex I countries that are not offsets hosts.

The leakage rates are driven by the international CO_2 leakage in covered sectors. However, the indirect effect to other sectors is relevant in the case of BCAs, for which it is negative, and in the case of direct linking, for which it is positive. These leakage rates follow the pattern on the CO_2 leakage rates, showing that emission changes in covered sectors will also drive emission changes in non-covered sectors.

Figure 3. World international carbon leakage rate under the different response policies in 2020 (% change wrt baseline)*



*With CDM, the computation of carbon leakage rates needs to account for the fact that the CDM substitutes emission reductions in non-Annex I countries for increases in their Annex I counterparts.

The alternative policies have different effects on carbon prices. As illustrated in Table 6, BCAs and offsets reduce carbon prices in all acting countries. Offsets reduce carbon prices further than BCAs in all acting countries except EU & EFTA and Other European Annex I countries. Offsets are particularly effective in lowering carbon prices in Japan, where the *Frag* scenario carbon price is particularly high. The gain from adding offsets to BTA is low as carbon prices diminish only slightly. This is a consequence of the fact that offsets already induce competitors in non-acting countries to reduce emissions and sell offset credits; the addition of BCAs then primarily acts to shift the financial burden of mitigation, without much effect on domestic reduction costs (see also Section 4.3 below). Direct linking reduces carbon prices for all

[10] As there is always an emission reduction in acting countries in the policy scenarios, a negative leakage rate necessarily means emissions are reduced also in non-acting countries.

[11] The modelling of offset systems is far from trivial, and our specification implies that host countries set up an ETS system to generate offset credits, and compensates emitters for their mitigation. This effectively rules out leakage to emission sources that are eligible for offset credits.

regions except Other European Annex I countries, for which the initial costs are very low. Permit flows are therefore largely from the Other European Annex I countries and Russia towards the other acting regions. The implementation of linking with other instruments further diminishes the carbon price, showing that the multiplicity of instruments has a positive effect on the carbon market.

Table 6. Carbon prices in acting countries in the different response policies in 2020 (USD 2004 / ton of CO_2)

Region	Frag	BCAs	Offsets	Link	Offsets_Link	Offsets_BCAs	Link_BCAs	All
Australia & New Zealand	57	46	35	39	27	38	32	28
Canada	94	81	63	39	27	64	32	28
EU & EFTA	54	36	37	39	27	38	32	28
Japan	126	110	84	39	27	88	32	28
Other European Annex I countries	1	0	1	39	27	1	32	28
USA	60	47	40	39	27	40	32	28
Russia	0	0	0	39	27	0	32	28
Acting*	***72***	***50***	***42***	***39***	***27***	***40***	***32***	***28***

*This is an average CO_2 price calculated as a weighted average on covered emissions reductions.

4.3 A variation on the imposed level of emission reduction

In the main scenario results described above, global emissions are kept constant throughout all policy simulations. This assumption is useful for comparing the welfare impacts of these policies: as the climate impacts are identical across scenarios, the benefits of these policies, which are not included in the modelling framework, are constant. In this framework, the cost-effectiveness of the policies can be evaluated. In reality, however, it is more common that governments of acting countries set their domestic or pooled policy targets, which are then kept constant when response policies are added to the policy mix. While this precludes a proper welfare evaluation (as the environmental benefits differ across scenarios), it is insightful for comparing the outcomes of these response policies.

This alternative assumption does not matter for the linking variants, but is important for the BCA case. The equal global emission level assumption of the main simulations effectively implies that when a BCA is introduced, domestic emission reduction efforts can be lowered, as part of the mitigation effort is shifted towards non-acting countries. This setting has strong similarities with the offset policy, which also shifts part of the mitigation effort to the non-acting countries. The main remaining difference between the two policies is that with BCAs acting countries reap the revenues of the tariff on imports, whereas with offsets acting countries compensate non-acting countries for their mitigation efforts. In the alternative case of equal domestic targets, the only influence of BCAs on domestic producers is through the competitiveness channel, not through the domestic stringency of the policy.

When domestic emissions of (the group of) Annex I countries are kept constant, BCAs are less effective in reducing output and welfare losses, as domestic emitters are still facing the same level of mitigation as in the *Frag* scenario. As non-acting countries are faced with an even higher BCA import tariff (as the domestic carbon prices in acting countries are higher), welfare losses in the *BCAs* scenario for the alternative setting are slightly higher than for the main scenario. Consequently, global welfare is lower. However, as the alternative scenario does lead to higher global emission reductions, no conclusion can be drawn in a cost-benefit perspective.

The BCA with equal domestic emission targets is less effective at protecting output of the domestic EIT sectors, although output losses are still much smaller than in the *Frag* policy scenario. It is also clear that in this alternative setting there is much more scope to combine the BCAs with offsets, as there is less overlap between the two response policies. The combination of these two policies (*Offsets_BCAs*) can be used to boost emission reductions in non-acting countries as much as possible (i.e. creating negative carbon leakage). When combining the BCA with direct linking of carbon markets (*Link_BCAs*), the interesting result emerges that the harmonised carbon prices induced by linking lead to lower BCA tariffs on imports from non-acting countries, and thus less emission reduction takes place in these countries. In this sense, in the presence of linking, and when corrective policies are less needed, the benefits from BCAs are lower.

Table 7. Comparison of results for different levels of emission reduction in 2020 (% change wrt baseline)

		Welfare			Output (EIT sectors)			Leakage rate*
		ACT	NACT	World	ACT	NACT	World	
Constant global emission reduction	*Frag*	-0.35	-0.45	-0.38	-2.7	1.5	-0.4	7.2
	BCAs	-0.06	-1.14	-0.40	-0.5	-0.6	-0.5	-17.6
	Offsets	-0.22	-0.35	-0.26	-1.9	0.9	-0.3	-2.3
	Link	-0.20	-0.32	-0.24	-1.9	1.0	-0.3	3.7
	Offsets_Link	-0.13	-0.26	-0.17	-1.4	0.6	-0.2	-1.8
	Offsets_BCAs	-0.05	-1.03	-0.36	-0.5	-0.5	-0.5	-9.1
	Link_BCAs	-0.04	-0.79	-0.27	-0.4	-0.4	-0.4	-12.6
	All	-0.03	-0.68	-0.24	-0.3	-0.4	-0.3	-6.8
Constant Annex I emission reduction	*Frag*	-0.34	-0.44	-0.38	-2.7	1.4	-0.4	6.2
	BCAs	-0.12	-1.48	-0.55	-0.7	-0.7	-0.7	-8.8
	Offsets	-0.22	-0.34	-0.26	-1.83	0.9	-0.3	1.0
	Link	-0.20	-0.32	-0.24	-1.9	1.0	-0.3	5.6
	Offsets_Link	-0.13	-0.25	-0.17	-1.3	0.6	-0.2	0.8
	Offsets_BCAs	-0.06	-1.04	-0.36	-0.51	-0.5	-0.5	-1.3
	Link_BCAs	-0.07	-0.96	-0.35	-0.5	-0.4	-0.5	-6.3
	All	-0.03	-0.69	-0.24	-0.35	-0.4	-0.4	-0.8

*This leakage rate, as in the following tables, corresponds only to international leakage in covered sectors, thus CO_2 only.

5. Sensitivity analysis

This section presents results of sensitivity analyses that help to understand the extent to which the response policies correct competitiveness losses and whether carbon leakage could be overstated. The first part of this sensitivity analysis considers modifications to the policy design. First it considers the case in which only OECD countries are participating to the linking coalition, and then the case in which BCAs only include import tariffs and not also export subsidies. The second part of the sensitivity analysis extends the scope of the mitigation policies to all GHGs sources and not only CO_2. When all gases are included, the effects are lower and thus the benefits from the response instruments are lower (Burniaux et al., 2012). The last sensitivity analysis considers smaller coalition sizes in which only three countries are acting. Sensitivity analysis on the main model parameters are not presented here, as these have been extensively investigated in Burniaux et al. (2012).

5.1. Sensitivity to policy design

In a first sensitivity analysis, the assumptions with respect to linking and BCA design are varied. For the linking case, a large part of the cost reductions come from the linking to the Other European Annex I (RA1) region, which has a much weaker reduction target (when compared to the baseline) than the other regions. Therefore, as an alternative, only linking between the OECD countries in Annex I is allowed. Secondly, in the BCA design specification, the case in which import tariffs are applied (and no export subsidies) is investigated.

Linking across OECD countries only is much less efficient in reducing welfare and output losses for acting countries. Given that carbon prices and domestic mitigation costs vary less across the OECD members of Annex I than within the full Annex I group confirms the general insight that linking is especially beneficial when participating countries have different characteristics. Welfare in non-acting countries also decreases further, especially in the *Link_BCAs* scenario, as BCAs entail additional costs for non-acting countries. Output in non-acting countries increases more in the case of linking with no BCAs if there is no room for linking with non-OECD members of Annex I. This is because, as acting countries loose more competitiveness when the linking is only between OECD countries, non-acting countries gain more international competitiveness. While linking does not substantively reduce leakage when only OECD countries are acting, BCAs are still effective in reducing carbon leakage.

Table 8. Sensitivity to policy design in 2020 (% change wrt baseline)

		Welfare			Output (EIT sectors)			Leakage
		ACT	NACT	World	ACT	NACT	World	rate
Sensitivity to linking coalition (OECD link only)	*Link*	-0.34	-0.43	-0.37	-2.6	1.3	-0.4	7.0
	Offsets_Link	-0.13	-0.26	-0.17	-1.3	0.6	-0.2	1.0
	Link_ BCAs	-0.06	-1.13	-0.39	-0.4	-0.6	-0.5	-9.6
	All	-0.06	-0.99	-0.35	-0.5	-0.5	-0.5	-1.3
Sensitivity to BCA design (only import tariffs)	*BCAs*	-0.02	-1.36	-0.44	-1.2	0.0	-0.5	-9.1
	Offsets_BCAs	-0.02	-1.22	-0.40	-1.1	0.0	-0.5	-1.1
	Link_BCAs	0.00	-0.96	-0.30	-0.9	0.1	-0.4	-6.0
	All	0.00	-0.83	-0.26	-0.8	0.0	-0.3	-0.7

In the case in which only import tariffs are implemented as part of BCAs (i.e. no export subsidies are imposed), there is an asymmetric treatment of the distortions created by the carbon pricing mechanisms, since the climate policy in acting countries increases their import prices without decreasing their export prices. As a consequence, non-acting countries are worse-off than in the case of both import tariffs and export subsidies. Similarly, world welfare is lower in this case. In absence of export subsidies, output losses are larger in acting countries. Thus, the import tariffs alone are not sufficient to correct the loss of competitiveness on the foreign market. As a consequence, welfare losses are slightly larger for acting countries in absence of export subsidies.

5.2. Sensitivity to coverage of emission sources

Generally, a wider coverage of the climate policy implies lower policy costs and higher efficiency. This is confirmed by the sensitivity analysis on different sources of emissions of GHGs. Table 9 illustrates results from the policies when all GHGs as well as emissions from other emission sources, such as agriculture, are considered. As before, the required overall GHG emission reduction targets are identical across scenarios; adding sources therefore means that the reduction efforts are shared more widely. When more sources of emissions are considered, the costs of all policies are lower and welfare is higher in all regions. As the policy is less costly for acting countries, the response policies implemented are less strict and therefore have a lower indirect effect on non-acting countries. Output losses in acting countries are also smaller, as the wider emission coverage leaves more flexibility. In non-acting countries, output is always slightly higher than in the baseline, while it was previously lower in the scenarios with BCAs. As a consequence, both global output and welfare losses are lower. The smaller changes in production and therefore emissions, lead to lower amounts of carbon leakage. This confirms the general insight that best solution to deal with leakage and competitiveness issues is a global carbon market that prices all sources of carbon, regardless of the sector, region or gas (cf. OECD, 2009).

Table 9. Sensitivity to the emission coverage size in 2020 (% change wrt baseline)

		Welfare			Output (EIT sectors)			Leakage rate
		ACT	NACT	World	ACT	NACT	World	
Sensitivity to emission coverage	*Frag*	-0.13	-0.19	-0.15	-1.0	0.6	-0.1	6.2
	BCAs	0.01	-0.51	-0.16	-0.4	0.0	-0.2	-6.6
	Offsets	-0.08	-0.14	-0.10	-0.6	0.3	-0.1	0.6
	Link	-0.05	-0.09	-0.06	-0.4	0.3	-0.1	3.8
	Offsets_Link	-0.03	-0.07	-0.04	-0.3	0.1	-0.1	0.3
	Offsets_BCAs	0.01	-0.42	-0.13	-0.4	0.0	-0.1	1.0
	Link_BCAs	0.01	-0.27	-0.08	-0.2	0.1	-0.1	-3.6
	All	0.01	-0.22	-0.06	-0.2	0.0	-0.1	1.1

5.3. Sensitivity to coalition size

The size of the coalition considered can also affect the results. This sensitivity analysis compares results between the cases of smaller coalitions of acting countries and the large coalition of all Annex I countries. Two alternative smaller coalitions are envisaged. The first considers Europe, Australia & New Zealand, and Other European Annex I countries, while the second the USA, Australia & New Zealand, and Other European Annex I countries. When the size of the coalition is smaller direct linking between Annex I acting countries appears to be more costly than indirect linking (through offsets) for non-acting countries as there is less scope for permit trading. The main results for the larger coalition showed the opposite result. As the coalition size is reduced, BCAs seem more efficient than (direct and indirect) linking in reducing both welfare and output losses in EIT sectors for acting countries. In other words, BCAs are especially effective when only a small group of countries act, as they more easily protect the domestic competitiveness when many countries are not acting. Linking carbon markets gains strength with the size of the coalition, as a larger coalition adds more flexibility of trade between acting countries. The shape of the coalition also matters. For example, combining offsets and BCAs is only welfare enhancing at the world level for the coalition including the USA, Australia & New Zealand and the Other European Annex I countries.

Table 10. Sensitivity to the coalition size in 2020 (% change wrt baseline)

		Welfare			Output (EIT sectors)			Leakage rate
		ACT	NACT	World	ACT	NACT	World	
Alternative coalition 1 (EU & EFTA, Australia & New Zealand, Other European Annex I countries)	*Frag*	-0.25	-0.10	-0.15	-2.3	0.5	-0.1	13.4
	BCAs	0.07	-0.28	-0.18	0.0	-0.2	-0.2	-11.2
	Offsets	-0.16	-0.08	-0.10	-1.7	0.4	-0.1	4.2
	Link	-0.14	-0.09	-0.11	-2.1	0.4	-0.1	11.6
	Offsets_Link	-0.10	-0.07	-0.08	-1.6	0.3	-0.1	4.0
	Offsets_BCAs	0.05	-0.26	-0.17	-0.2	-0.1	-0.1	-1.5
	Link_BCAs	0.09	-0.23	-0.13	-0.1	-0.1	-0.1	-8.2
	All	0.07	-0.21	-0.12	-0.2	-0.1	-0.1	-1.9
Alternative coalition 2 (USA, Australia & New Zealand, Other European Annex I countries)	*Frag*	-0.30	-0.07	-0.14	-4.3	0.6	-0.2	8.0
	BCAs	-0.05	-0.12	-0.10	-1.1	0.0	-0.2	-5.6
	Offsets	-0.18	-0.06	-0.09	-2.9	0.4	-0.2	3.9
	Link	-0.21	-0.08	-0.12	-4.5	0.6	-0.2	8.3
	Offsets_Link	-0.15	-0.07	-0.10	-3.6	0.5	-0.2	4.2
	Offsets_BCAs	-0.03	-0.10	-0.08	-1.0	0.0	-0.2	2.0
	Link_BCAs	-0.01	-0.12	-0.08	-1.2	0.0	-0.2	-5.6
	All	0.00	-0.10	-0.07	-1.1	0.0	-0.2	1.7

6. Conclusion

The recent and ongoing climate change negotiations suggest that international climate policy action will likely be built out of a collection of fragmented domestic actions, rather than being globally coordinated. Fragmented carbon markets give rise to international differences in carbon prices. Countries undertaking climate action are raising concerns on the domestic welfare, output losses, and carbon leakage. Border carbon adjustments (BCAs) have been proposed as a possible solution to protect the domestic markets of acting countries. This paper analyses the effectiveness of BCAs, considered as both import tariffs and export subsidies levied by acting countries on non-acting countries, in restoring competitiveness in acting countries, but also considers alternative, more cooperative response policies. In particular, the paper considers direct and indirect linking as a means to level carbon prices across countries, to reduce carbon leakage and output and trade losses. In the analysis, 'indirect' linking refers to the possibility for acting countries to use a common pool of carbon offsets, as in the case of the CDM. While the numerical results derived in this paper depend on the specification of the model, and robust conclusions on the efficiency ordering of these instruments cannot be derived, a number of conclusions can be drawn.

First, the simulation results illustrate that a fragmented climate policy can lead to competitiveness losses for acting countries: output of EIT sectors and exports of EIT goods are reduced. This is often to the advantage of non-acting countries where production and exports mostly increase to compensate the losses in acting countries. The shift in production from acting to non-acting countries leads to carbon leakage, although limited. This decreases the effectiveness of the carbon policy as it is the global emission reduction that matters for climate change impacts. There are relevant welfare losses in acting countries as well as in those non-acting countries that most heavily rely on energy exports, as they are negatively affected by the reduced demand (and hence lower prices) for energy.

Second, both BCAs and linking can be considered as effective response measures to these issues. If the aim of the response measure is to preserve the competitiveness of acting countries, BCAs could be included in the policy mix. In the main scenarios considered, BCAs shift the burden of emission reductions to non-acting countries and are thus more effective in restoring competitiveness than linking. In particular, while both BCAs and offsets shift part of the emission reductions to non-acting countries, in the case of BCAs the associated cost is borne by non-acting countries, whereas in the case of offsets non-acting countries receive full compensation for the reduced emissions. Although BCAs are more efficient from the point of view of acting countries, there is still a small negative effect on welfare in the presence of BCAs. Therefore, there is still scope for using linking in the policy mix when BCAs are imposed, as in this case welfare losses decrease in both acting and non-acting countries.

If the aim of the response measure is instead to reduce welfare losses at global level, the situation is reversed. While BCAs are effective for acting countries, they cause severe welfare and competitiveness losses for non-acting countries. BCAs are less effective than linking in reducing global welfare losses. Only in the case in which BCAs are combined with linking they can achieve lower welfare losses, although the inequality across acting and non-acting countries persists.

Third, the sensitivity analysis clearly shows that extending carbon markets to more emission sources or widening the participation of countries to the climate policy increases the effectiveness of linking with respect to BCAs. This confirms the main insights from OECD (2009) that the best solution to deal with leakage and competitiveness issues is to work towards a global carbon market that prices all sources, regardless of sector, region or gas.

One important caveat to these welfare and competitiveness assessments is that they assume idealised policy instruments with no transaction costs and no uncertainty on delivery. In reality, there are numerous market imperfections and policy distortions which may prevent some of the abatement potential from being fully reaped. These include transaction costs and bottlenecks, information barriers, credit market constraints, and institutional and regulatory barriers to investment in host countries. The well-functioning crediting mechanism that is modelled here is largely equivalent to an international (asymmetric) ETS covering all non-Annex I countries, in which each of them is assigned a target equal to their baseline emissions.

A second caveat is that the political economy aspects of these instruments should be further explored to give effective insights to policy-makers. This paper also neglects to consider further decomposition analysis of the effects found, such as domestic as opposed to terms of trade effects or drivers of welfare impacts. This could be considered in future work.

These caveats notwithstanding, the analysis in this paper clearly shows that instruments to deal with competitiveness concerns arising from fragmented carbon markets are available, and a clever policy mix can both enhance environmental effectiveness and economic efficiency of climate policy, by largely levelling carbon prices.

Disclaimer

The views expressed in this paper are those of the authors and do not necessarily represent the views of the OECD or of its member countries.

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ANNEX A: Details of the ENV-Linkages model

Figure A.1. Production structure of a generic (non-agriculture and non-energy) sector in ENV-Linkages

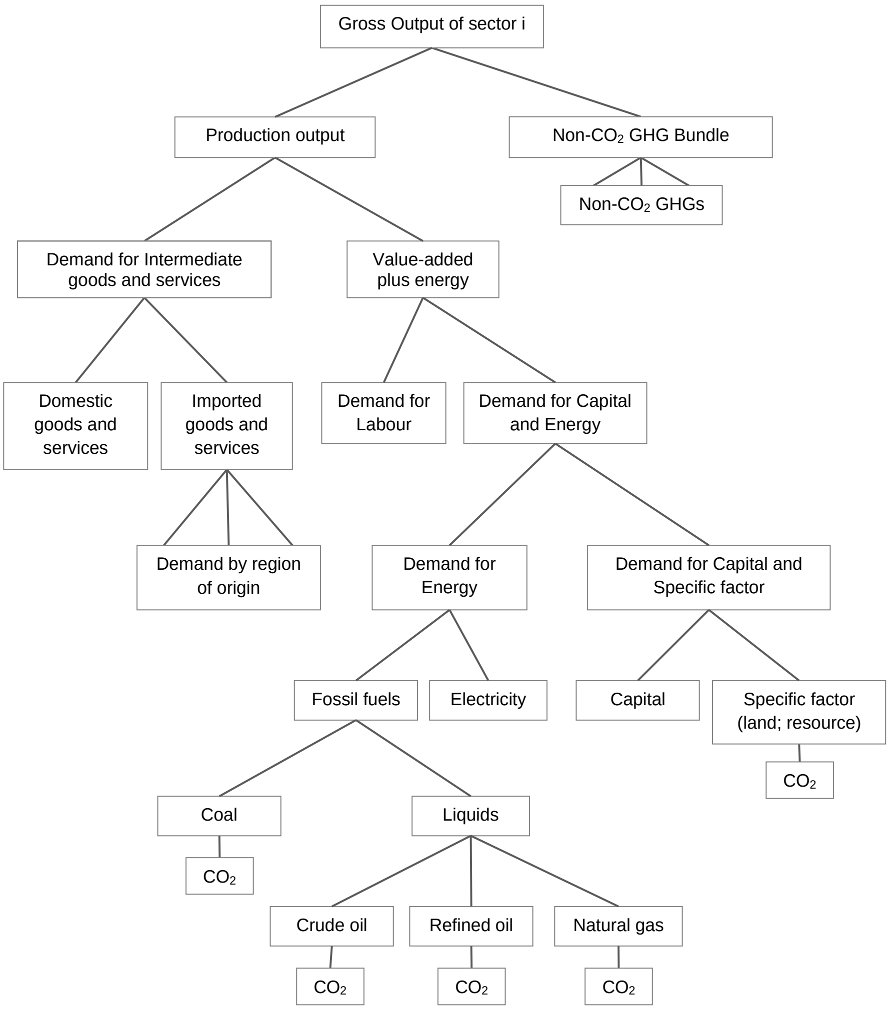
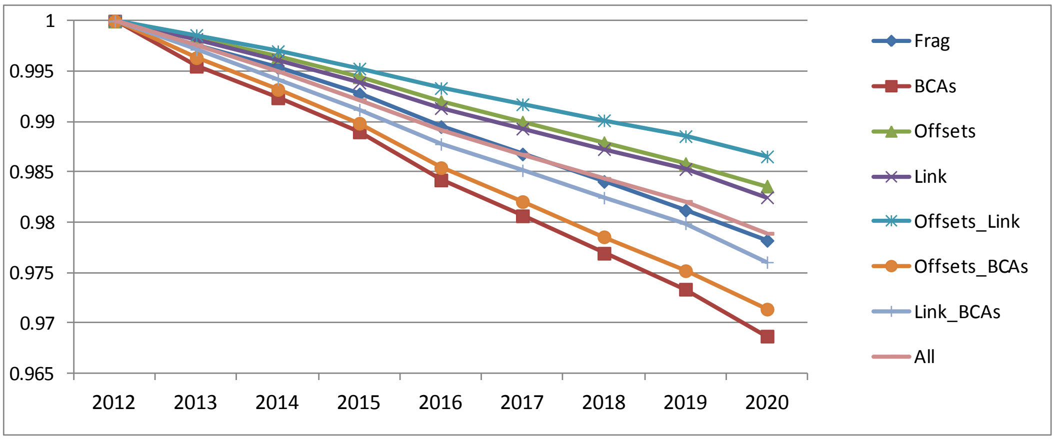


Table A.1. Key indicators in the baseline scenario at 2012

Region	GDP PPP (2004 USD)	GHG Emissions (Mtoe)	Output of EIT sectors (2004 USD)	Carbon Intensity of GDP (Mtoe/th. 2004 USD)
Australia & New Zealand	1037647	697	84332	0.67
Canada	1321846	725	122254	0.55
EU & EFTA	16023231	5040	1826890	0.31
Japan	4317132	1244	675107	0.29
Other European Annex I countries	1628964	966	97076	0.59
Russia	2419655	2393	69794	0.99
USA	15315406	7063	1275699	0.46
Brazil	2424281	1249	118510	0.52
China	15186557	10464	2134493	0.69
Energy exporting countries	6269294	3873	254837	0.62
Indonesia	1325298	811	78115	0.61
India	5485267	2642	202413	0.48
Korea	1677081	671	241501	0.40
Mexico	1596360	577	107062	0.36
South Africa	569755	453	69923	0.80
Other high and middle income countries	5138686	2635	401464	0.51
Other low income countries	2880679	2876	86595	1.00

Figure A.2. Oil price (indexed to baseline price) in the different scenarios



ANNEX B: Regional results

Table B.1. Impacts of response policies on welfare by region in 2020 (% change wrt baseline)

Region	Frag	BCAs	Offsets	Link	Link_Offsets	Offsets_BCAs	Link_BCAs	All
Australia & New Zealand	-0.89	-0.46	-0.58	-0.09	-0.09	-0.40	0.04	0.02
Canada	-1.43	-1.15	-0.99	-0.76	-0.57	-0.94	-0.59	-0.53
EU & EFTA	-0.20	0.08	-0.13	-0.08	-0.04	0.06	0.11	0.10
Japan	-0.39	0.07	-0.22	-0.35	-0.23	0.08	-0.16	-0.14
Other European Annex I countries	0.14	0.14	0.11	1.96	1.46	0.14	1.59	1.42
Russia	-1.15	-1.19	-0.89	-0.15	-0.12	-1.15	-0.35	-0.30
USA	-0.31	-0.02	-0.18	-0.34	-0.24	-0.02	-0.15	-0.13
Acting countries	-0.35	-0.06	-0.22	-0.20	-0.13	-0.05	-0.04	-0.03
Brazil	-0.18	-0.44	-0.15	-0.14	-0.11	-0.40	-0.32	-0.28
China	-0.25	-1.53	-0.20	-0.12	-0.11	-1.35	-0.99	-0.84
Energy exporting countries	-1.34	-1.99	-1.04	-1.07	-0.84	-1.82	-1.49	-1.32
Indonesia	-0.48	-0.85	-0.38	-0.29	-0.24	-0.76	-0.53	-0.46
India	-0.06	-0.67	-0.05	-0.01	-0.02	-0.61	-0.51	-0.43
Korea	-0.05	-0.23	-0.02	0.03	0.03	-0.20	-0.09	-0.07
Mexico	-0.26	-0.38	-0.20	-0.18	-0.15	-0.34	-0.27	-0.24
South Africa	-0.32	-0.90	-0.23	-0.23	-0.17	-0.79	-0.57	-0.49
Other high and middle income countries	-0.26	-0.75	-0.20	-0.23	-0.19	-0.68	-0.55	-0.48
Other low income countries	-0.45	-1.14	-0.35	-0.32	-0.26	-1.03	-0.79	-0.68
Non-acting countries	-0.38	-0.40	-0.26	-0.24	-0.17	-0.36	-0.27	-0.24
World	-0.89	-0.46	-0.58	-0.09	-0.09	-0.40	0.04	0.02

Table B.2. Impacts of response policies on EIT sectors' output by region in 2020 (% change wrt baseline)

Region	Frag	BCAs	Offsets	Link	Link_Offsets	Offsets_BCAs	Link_BCAs	All
Australia & New Zealand	-8.9	0.3	-5.6	-7.3	-5.3	0.0	-0.6	-0.7
Canada	-10.2	-7.8	-7.6	-4.0	-2.9	-6.4	-2.5	-2.2
EU & EFTA	-1.3	0.3	-0.9	-0.6	-0.4	0.1	0.4	0.3
Japan	-5.7	-1.8	-4.0	-1.2	-0.8	-1.5	-0.1	-0.1
Other European Annex I countries	2.1	1.7	1.6	-7.6	-5.6	1.5	-3.9	-3.5
Russia	4.9	4.5	3.6	-15.4	-11.0	4.3	-5.2	-5.0
USA	-3.3	-1.0	-2.2	-2.0	-1.4	-0.9	-0.6	-0.5
Acting countries	-2.7	-0.5	-1.9	-1.9	-1.3	-0.5	-0.4	-0.3
Brazil	1.8	-0.2	1.2	1.4	0.9	-0.1	-0.2	-0.1
China	0.9	-0.8	0.4	0.6	0.2	-0.7	-0.5	-0.5
Energy exporting countries	3.4	-1.3	2.5	2.8	2.1	-1.0	-1.0	-0.7
Indonesia	2.7	-0.1	1.9	1.7	1.2	0.0	0.0	0.0
India	1.6	-0.6	0.8	1.3	0.7	-0.5	-0.5	-0.5
Korea	2.5	0.8	1.8	1.6	1.3	0.8	0.4	0.5
Mexico	1.9	0.0	1.2	1.3	0.9	0.0	0.0	0.0
South Africa	2.0	-0.3	1.4	1.4	1.0	-0.1	-0.1	-0.1
Other high and middle income countries	2.6	0.1	1.7	1.9	1.3	0.2	0.1	0.1
Other low income countries	2.4	-1.5	1.4	2.0	1.2	-1.5	-1.4	-1.2
Non-acting countries	1.5	-0.6	0.9	1.0	0.6	-0.5	-0.4	-0.4
World	-0.4	-0.5	-0.3	-0.3	-0.2	-0.5	-0.4	-0.3

Table B.3. Impacts of response policies on EIT goods' exports by region in 2020 (% change wrt baseline)

Region	Frag	BCAs	Offsets	Link	Link_Offsets	Offsets_BCAs	Link_BCAs	All
Australia & New Zealand	-17.3	1.5	-11.0	-13.9	-10.1	0.5	-0.3	-0.6
Canada	-12.9	-11.0	-9.6	-5.3	-3.8	-8.9	-3.7	-3.3
EU & EFTA	-1.3	0.2	-0.9	-0.6	-0.4	-0.1	0.2	0.1
Japan	-10.4	-6.7	-7.2	-2.1	-1.4	-5.6	-1.7	-1.4
Other European Annex I countries	2.7	1.8	2.0	-9.2	-6.8	1.7	-4.0	-3.6
Russia	8.4	7.8	6.2	-20.7	-14.8	7.4	0.7	-0.6
USA	-5.3	-2.2	-3.5	-3.1	-2.1	-1.9	-1.3	-1.2
Acting countries	-3.1	-0.9	-2.1	-2.4	-1.7	-0.9	-0.5	-0.5
Brazil	4.8	-3.1	3.1	3.5	2.3	-2.6	-2.1	-1.7
China	4.1	-7.7	2.4	2.8	1.7	-6.5	-4.6	-3.9
Energy exporting countries	4.7	-4.4	3.5	3.5	2.7	-3.8	-3.3	-2.6
Indonesia	4.8	-2.5	3.3	2.9	2.0	-1.9	-1.2	-1.0
India	3.2	-6.0	1.7	2.6	1.4	-5.5	-5.0	-4.3
Korea	2.4	0.1	1.8	1.8	1.4	0.2	0.4	0.4
Mexico	5.6	0.8	3.7	3.9	2.7	0.8	0.8	0.8
South Africa	4.9	-2.7	3.4	3.5	2.5	-2.1	-1.9	-1.5
Other high and middle income countries	3.0	-1.0	2.0	2.2	1.5	-0.8	-0.4	-0.3
Other low income countries	5.2	-6.5	3.2	4.0	2.5	-6.0	-5.4	-4.6
Non-acting countries	3.9	-3.9	2.5	2.8	1.9	-3.3	-2.5	-2.1
World	-0.5	-2.0	-0.4	-0.5	-0.4	-1.8	-1.3	-1.1

Table B.4. Impacts of response policies on EIT sectors' imports by region in 2020 (% change wrt baseline)

Region	Frag	BCAs	Offsets	Link	Link_Offsets	Offsets_BCAs	Link_BCAs	All
Australia & New Zealand	0.0	-2.4	-0.2	0.5	0.2	-2.0	-1.4	-1.2
Canada	0.2	-2.0	0.1	-0.4	-0.3	-1.7	-1.3	-1.1
EU & EFTA	-0.4	-1.4	-0.3	-0.5	-0.4	-1.4	-1.4	-1.2
Japan	5.8	-11.7	3.8	0.8	0.5	-9.7	-5.3	-4.5
Other European Annex I countries	-0.7	-0.6	-0.5	0.6	0.4	-0.6	-0.1	0.0
Russia	-2.5	-2.1	-1.9	5.7	3.8	-2.1	4.5	3.9
USA	2.3	-3.8	1.3	1.2	0.7	-3.3	-3.1	-2.6
Acting countries	0.5	-2.6	0.2	0.2	0.1	-2.3	-1.8	-1.5
Brazil	-1.8	-0.8	-1.2	-1.6	-1.1	-0.8	-0.3	-0.3
China	-2.6	-2.1	-1.7	-1.6	-1.0	-1.8	-0.9	-0.8
Energy exporting countries	-1.2	-2.0	-0.9	-1.5	-1.1	-1.8	-1.4	-1.3
Indonesia	-1.4	-1.1	-1.0	-1.2	-0.8	-1.0	-0.5	-0.4
India	-2.8	-0.8	-1.7	-2.4	-1.5	-0.9	-0.5	-0.4
Korea	-1.9	-0.5	-1.4	-1.1	-0.9	-0.5	0.0	-0.1
Mexico	-5.2	-0.6	-3.5	-3.5	-2.4	-0.7	-0.4	-0.4
South Africa	-0.5	-1.1	-0.4	-0.3	-0.2	-1.1	-0.9	-0.8
Other high and middle income countries	-1.0	-0.6	-0.7	-0.9	-0.7	-0.6	-0.1	-0.1
Other low income countries	-0.4	-0.7	-0.2	-0.6	-0.4	-0.7	-0.5	-0.4
Non-acting countries	-1.8	-1.3	-1.2	-1.4	-1.0	-1.2	-0.7	-0.6
World	-0.5	-2.1	-0.4	-0.5	-0.4	-1.9	-1.3	-1.1