THE ROLE OF COMPETITIVENESS INSTRUMENTS IN THE CLIMATE POLICY DEBATE – ADDRESSING FRAGMENTED CARBON MARKETS

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Abstract: As countries advance in climate change mitigation policy, with different timing and approaches, fragmented carbon markets are emerging. Differences in climate change policy approaches may have impacts on the relative competitiveness of internationally operating energy-intensive sectors in countries with more stringent policies. These concerns have stimulated a debate on the design of climate policies as well as on additional policies that could reduce the negative impacts of climate policies on competitiveness. This paper examines the competitiveness impacts of a range of stylised global mitigation scenarios, plus investigates common policy instruments to address competitiveness impacts of climate policies. The analysis uses the OECD's global recursive-dynamic general equilibrium model ENV-Linkages. The paper focuses on border tax adjustments, and both direct and indirect linking (i.e. offsets). The different policy instruments to address competitiveness have implications on economic efficiency, environmental impacts, and international competitiveness for both acting countries and countries that do not participate directly in climate policy. This paper compares the implementation of these instruments with a climate policy without additional instruments to deal with competitiveness using a range of metrics, such as welfare, carbon leakage and output.

A key finding from the analysis is that while the temporary use of these policy instruments may ease the transition of Emission-Intensive, Trade-Exposed Industries (EITs) to a low-emission economy, all have important drawbacks. A ranking of these instruments depends crucially on which metric is deemed most important. Further, as more countries adopt climate change mitigation policies, the benefits of instruments to address competitiveness concerns quickly diminish.

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 issue and one of the main international challenges of our time. Recently, the participation of countries has been gradually increasing but the path to achieve larger participation is still unclear. 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. Further, as countries advance in climate change mitigation policy, with different timing and approaches, fragmented carbon markets are emerging. Many countries are worried that strong unilateral reductions could foster "carbon leakage", leading to domestic welfare losses and undermining the international competitiveness of domestic industries. These concerns have stimulated a debate on the design of climate policies as well as on additional policies that could reduce the negative impacts of climate policies on competitiveness. 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 competitiveness impacts, as their high emission intensity implies relatively high production cost increases 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 a carbon policy. BCAs are considered to be a measure to "level the playing field" (see Burniaux, *et al.*, 2012, Bernard *et al.*, 2001; Fischer and Fox, 2009), that is to 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. The environmental rationale for BCAs is that they would reduce carbon leakage and provide incentives for other countries to join an international coalition by punishing free-riding. Even when carbon leakage is limited, BCAs can contribute to reduced competitiveness and output losses in domestic energy-intensive industries exposed to international competition through levelling domestic and imported prices (Babiker, 2005; Demailly and Quirion, 2006).

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 analysis in CGE frameworks 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 (i.e. by joining the international coalition).

The purpose of this paper is to analyse whether more cooperative policy actions than BCAs 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 design 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 smooth distortions across countries (Jaffe and Stavins, 2007). The paper considers direct linking as well as 'indirect' linking. In this analysis, the possibility to use a common pool of carbon offsets by all acting countries is considered as 'indirect' linking (Dellink *et al.*, 2010). 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. The direct linking instrument considered is the implementation of unlimited permit trading between all acting countries (OECD, 2009a).

The analysis first draws upon global mitigation scenarios presented in the OECD *Environmental Outlook* to 2050 (OECD, 2012) to investigate the competitiveness impacts of such policies. The analysis focuses on results to 2020 as from 2021 onwards all mitigation scenarios assume a burden sharing regime minimising competitiveness impacts. A decomposition analysis is undertaken to help understand to what extent changes to the design of the fragmented carbon scheme has on competitiveness impacts and carbon leakage rates.

The analysis then focuses on comparing these more cooperative policy instruments to BCAs on 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 EIT sectors' output and domestic and international competiveness for the acting countries, and (3) reduce the presence of carbon leakage. As the corrective policies considered here are all 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 illustrate that a fragmented climate policy can lead to substantial 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. If the aim of the response measure is to preserve the competitiveness of acting countries, BCAs could be included in the policy mix as they 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 severe welfare and competitiveness losses for non-acting countries. As a result, BCAs are less effective than linking in reducing global welfare losses.

The remainder of the paper is structured as follows. Section 2 presents an overview of the modelling framework used for the analysis, Section 3 outlines assess indicators of competitiveness using scenarios from the OECD *Environmental Outlook to 2050* (OECD, 2012) and Section 4 presents the main results of the policy scenarios. Section 5 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 Computable General Equilibrium (CGE) model. The ENV-Linkages model is the successor to the OECD GREEN model for environmental studies (Burniaux, *et al*. 1992). 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 in Annex 1). 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, on one hand, and all other inputs, on the other hands. 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 the “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 (SF_6, 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. One important implication from this assumption in the context of this paper is that real exchange rates immediately adjust to restore current account balance when countries start exporting/importing emission permits.

Finally, it should be stressed that the ENV-Linkages model does not assess the impacts from climate change, and can therefore not determine the benefits from mitigation action through reduced damages.

2.2. Data and calibration of the baseline scenario

The version of the model used here represents the world economy in 17 regions, each with 27 economic sectors, as illustrated in Table 1. These include seven 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 the 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	Australian and New Zealand (ANZ)
Crude oil	Canada (CAN)
Gas	European Union – EU-27 plus EFTA (WEU)
Refined oil products	Japan (JPN)
Electricity*	Russia (RUS)
	Other European Annex I countries (RA1)
Emission-intensive & trade-exposed sectors	United States of America (USA)
Chemicals	
Non-metallic minerals	*Non-Annex1 regions*
Iron and steel industry	Brazil (BRA)
Non-ferrous metals	China (CHN)
Paper–pulp–print	India (IND)
Fabricated Metal Products	Indonesia (IDN)
	Korea (KOR)
Forestry, agriculture and fisheries	Mexico (MEX)
Rice	Other Energy Exporting countries, Middle-East and North Africa (EEX)
Other crops	Other middle income countries (MIC)
Livestock	Other low income countries (LIC)
Forestry	South Africa (ZAF)
Fishery	
Other industries and services	
Transport services	
Other Manufacturing	
Services	
Construction & Dwellings	
Other Mining	
Food Products	

* Electricity is split into 7 sectors: nuclear power, solar and wind electricity, renewable combustibles and waste electricity, fossil fuel based electricity, coal electricity with CCS, gas electricity with CCS and hydro and geothermal electricity.

The Baseline scenario assumes that there are no new climate policies, and projects future emissions on the basis of assumptions on the long-term evolution of output growth, relative prices of fossil fuels, and potential gains in energy efficiency. It thus provides a benchmark against which policy scenarios aimed at achieving emission cuts can be assessed.

The construction of the economic baseline scenario used for this model is described in detail in the OECD Environmental Outlook to 2050 (OECD, 2012) and especially in Chateau *et al.* (2011). It is built on various exogenous trends: employment levels that are derived from labour force projections and from estimates of national unemployment rates provided by the OECD; labour productivity projections, which are based on a conditional-convergence hypothesis (for details see Duval and de la Maisonneuve, 2010); autonomous energy efficiency factors and fossil-fuel production are calibrated on IEA World Energy Outlook projections (IEA, 2010a and 2010b), while emissions of non-CO2 fossil-fuel combustion greenhouse gases are 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 constant 2010 USD using Purchasing Power Parities (PPPs).

3. Assessing competitiveness impacts of global mitigation policies

3.1. Defining competitiveness and carbon leakage

As a result of perceived or real differences between countries in the stringency of climate policy and thus differences in domestic carbon prices, many countries have expressed concerns for loss of competitiveness and potential carbon leakage. 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 competitiveness impacts, as their high emission intensity implies relatively high production cost increases and their trade exposure implies limited options for passing on the costs of carbon pricing.

This section discusses indicators to assess competitiveness issues at a national and sectoral level under the scenarios described above. Competitiveness is a comparative concept and its measurement is challenging (Krugman, 1994). It is important to distinguish the concept of comparativeness at a national, sectoral and firm level as at each level competitiveness has different implications and meanings (Reinaud, 2008). Competitiveness issues for countries adopting climate change policies may be evident through reductions in economic output, changes in trade flows, investment patterns, employment and interest and exchange rates. Whereas, firms operating in energy intensive and trade exposed sectors will look to profits as the key indicator of competitiveness related issues from climate change policy (Reinaud, 2008). There are many factors that contribute to the competitiveness of an individual firm. These factors include costs of primary factors, energy, raw materials, availability of labour, proximity to markets, ability to generate product innovations, quality of products and service standards and interest and exchange rates (Reinaud, 2008; OECD, 2010a). In the short-term, in a scenario where a sector may face a competitiveness loss, market share may be reduced in countries that adopt climate mitigation policies, as competing sectors from abroad without similar climate mitigation policies gain market share. In the long term, investment and capital may also shift to non-participating countries (Reinaud, 2008; Dröge, 2009). The focus of this paper is concentrated on national and regional sector measures of competitiveness, not on impacts for individual firms.

The environmental consequence of shifts in production related to international competitiveness issues is referred to as carbon leakage (Aldy and Pizer, 2009; Stern, 2006). Carbon leakage is characterised by shifts in emissions from countries where climate mitigation policies are adopted to countries where climate mitigation policies are less stringent. Carbon leakage is defined as the ratio of emission increases from a specific sector in countries that do not face stringent climate mitigation policies over emission reductions from the sector in countries that face climate mitigation policies.

Despite being closely related, competiveness and carbon leakage are two distinct concepts. Carbon leakage may be caused by other mechanisms than competitiveness. Carbon leakage can arise through two main channels (Burniaux, et. al, 2012). The first channel is the international competitiveness trade channel where emission-intensive, trade-exposed industries in countries with stringent mitigation policies lose market share. The second channel of leakage, which is not directly related to international competitiveness is the fossil-fuel channel. The fossil fuel channel operates as agents substitute away from emission intensive goods in acting countries, which reduces the world demand for fossil fuels. In turn, world market prices of fossil fuels decline resulting in greater use of fossil fuels and higher emissions in non-acting countries.

This paper focuses on indicators of the international competitiveness trade channel. In the following section we outline indicators of competitiveness, firstly at national level through indicators such as welfare, GDP, terms of trade and investments in physical capital. The welfare measure used in this analysis is the Hicksian equivalent real income variation. It is defined as the change in real income necessary to ensure the same level of utility to consumers as in the baseline projection. It is the preferred measure of welfare as real GDP does not value the welfare impacts when large volumes of emission permit trading occur (OECD, 2009b). We then examine potential competitiveness and carbon leakage issues at the sectoral level, applying indicators such as sectoral output, exports and market share for emission-intensive industries. Combining information from these two sets of indicators is of particular interest to governments and policymakers seeking to reduce the potentially negative effects of climate change mitigation policy in fragmented carbon markets on emission-intensive industries.

3.2 Overview of global scenarios to assess competitiveness impacts

The policy scenarios used to assess the competitiveness impacts of global mitigation policies are based on the scenarios used in the OECD *Environmental Outlook to 2050* (OECD, 2012). A reference scenario in which GHG emissions are stabilised at 450 ppm by the end of the 21^{st} century (*450 Core*) is used as a benchmark for the assessment of competitiveness impacts of climate change mitigation policies to 2020. The *450 Core* scenario describes a fully harmonised carbon market that encompasses all regions, sector and gasses. This scenario assumes timing least-cost allocation of emission reductions and the use of all available mitigation options, including biomass energy with carbon capture and storage (BECCS). To stabilise GHG emissions at 450 ppm the scenario assumes that carbon is priced starting in 2013 and that low cost abatement opportunities are immediately available in all regions, sectors and gasses. Permits are initially (i.e. in 2013) allocated based on current shares of countries in global emissions, but the allocation rule gradually changes to equal per-capita emissions by 2050.

The *450 Core* scenario is used as the cost-effective reference point against which to compare additional scenarios. The scenario assumes a globally-coordinated response to climate change through a fully harmonised carbon market. As all countries are acting, the competitiveness impacts of the climate policy are small. To assess competitiveness impacts from alternative arrangements of a global climate change policy, we consider alternative scenarios from the OECD *Environmental Outlook to 2050* (OECD, 2012).

The first alternative policy scenario examined is the *450 Delayed Action* scenario. This scenario assumes that it may not be realistic to expect large emission reductions in the coming decade. The scenario reflects the high end of pledges made in the Copenhagen Accord and Cancún Agreements with strict land-use accounting rules and inability to carry over surplus emission credits from the current Kyoto Protocol commitment period. In contrast to the *450 Core* scenario, the *450 Delayed Action* scenario assumes that domestic carbon markets are not linked to each other until 2020. It also assumes that significant additional effort would have to be made after 2020 to "catch-up" and substantial increases in emission reduction rates will be required to achieve 450ppm by the end of the century. After 2020, the permit allocation rule is identical to that of the *450 Core* scenario.

To investigate the competitiveness impacts of changing the permit allocation rule, we investigate an alternative policy scenario that has the same global emission pathway as the *450 Core* scenario. However, this scenario assumes immediately from 2013 per capita emission allowances are equal across countries (*450 Per Capita*).

The analysis compares each of the policy scenarios against the reference policy scenario to assess the competiveness impacts of the alternative climate change mitigation scenarios. The policy scenarios are described in more detail in the OECD *Environmental Outlook to 2050* (OECD, 2012). Table 2 summarises the scenarios considered in the analysis.

Table 2. Policy scenarios

Scenario	Description
Reference policy	
450 Core	Global carbon market. Policy starts in 2013; full flexibility across time, sources and gases. Contraction and convergence permit allocation rule
Climate stabilisation scenarios	
450 Delayed Action	As 450 Core, but until 2020 no mitigation action beyond Cancún and Copenhagen pledges; fragmented regional carbon market
Alternative permit allocation rules	
450 Per Capita	As 450 core, but per capita emission allowances are equal across countries

3.3. Macroeconomic indicators of competitiveness

The assessment of competitiveness impacts of climate change mitigation policies are benchmarked relative to the *450 core* scenario in 2020. The *450 core* scenario is a fully harmonised carbon market that encompasses all regions, sector and gasses. Competitiveness impacts are minimal in the *450 Core* scenario as the mitigation policy is of full harmonisation. Table 3 illustrates how key macroeconomic indicators of competitiveness are affected by the *450 Delayed Action* mitigation policy. Note that it is impossible to compare the cost-effectiveness of these two policies, as the level of global emission reduction is not identical, and therefore the benefits of these policies in terms of avoided climate damages differ.

Table 3. Competitiveness impacts of the *450 Delayed Action* scenario, 2020: % change from *450 Core* scenario

Region	Welfare	GDP	Investment	Terms of Trade	GHG Emissions	Real carbon Price* USD/tCO_2e
Canada	-0.3	-0.3	-0.7	0.2	-11.1	31.8
EU and EFTA	-0.2	-0.1	-0.2	-0.1	-3.3	18.6
Japan and Korea	-0.4	-0.3	-1.0	0.1	-15.8	58.2
Oceania	-0.6	-0.3	-1.4	0.2	-13.6	39.4
Russia	0.1	0.0	0.2	0.2	19.3	0.2
Rest of Annex I	-0.2	0.0	-0.3	-0.2	13.1	0.4
USA	0.0	0.0	0.2	0.1	-2.6	10.5
Brazil	0.2	0.0	0.1	0.1	-0.1	6.6
China	0.5	0.2	0.4	-0.3	11.7	1.2

India	-0.7	0.0	-1.3	-1.2	12.6	0.7
Indonesia	-0.6	-0.1	-1.0	-0.6	1.5	4.5
M. East and N. Africa	0.2	-0.1	0.0	0.5	14.1	
Mexico	0.0	0.0	0.0	0.1	-2.2	10.1
South Africa	0.3	-0.1	-0.4	1.1	-9.1	17.0
Rest of the world	-0.2	0.1	-0.4	-0.1	7.9	
World	***-0.1***	***0.0***	***-0.2***		***5.6***	

* Carbon prices in the *450 Delayed Action* scenario, not deviations from *450 Core*.

Due to the fragmentation of the carbon market in the *450 Delayed Action* scenario, emission reductions are smaller than the *450 Core* scenario and welfare losses are greater for most regions in 2020. Investment losses in most regions are also greater than in the *450 Core* scenario despite the smaller reductions in emissions especially in regions with relatively higher carbon prices. As a result of improved terms of trade, regions such as the USA experience a slight increase in welfare. Domestic mitigation efforts also have substantial indirect effects; especially through the international fossil fuel markets, where there is a downward pressure on prices (and hence lower income for fossil fuel exporters) resulting from the reduced demand for energy in acting countries. For regions such as Oceania and Japan and Korea, welfare losses are compounded by changes in their international competitiveness position and domestic demand changes.

In the *450 Delayed Action* scenario, carbon prices vary largely between zero for regions without pledges such as the Middle East and North Africa and the rest of the world, to USD \$58/tCO_2e for Japan and Korea as permit trading is not allowed in this scenario. In comparison, the carbon price in the *450 Core* scenario equals USD \$7.0/tCO_2e. Furthermore, as some low-cost mitigation options are not taken-up this results in higher global costs.

Table 4 shows the macroeconomic indicators of competitiveness for the *450 Per capita* scenario relative to the benchmark *450 Core* scenario. Globally, as all the alternative permit allocation rule scenarios have the same global emission pathway as the *450 Core* scenario, the welfare measure is unchanged. However there are substantial distributional effects between regions. Heavily populated and developing regions such as India, Indonesia and countries within the rest of the world benefit from this scheme as they become large exporters of permits. In contrast, regions such as Canada, Oceania and the USA face relatively higher costs as these regions are forced to import permits to meet their permit allocation and consequentially experience a deterioration in their terms of trade. Interestingly for China emission growth outweighs growth in population, requiring China to import permits under the *450 Per capita* scenario resulting in higher welfare losses.

Table 4. Competitiveness impacts of the *450 Per capita* scenario, 2020: % change from *450 Core* scenario

Region	Welfare	GDP	Investment	Terms of Trade	GHG Emissions	Real carbon Price* USD/tCO_2e
Canada	-0.4	0.0	-0.4	-0.1	-0.1	7.0
EU and EFTA	-0.2	0.0	0.0	0.0	-0.1	12.0**
Japan and Korea	-0.1	0.0	-0.1	-0.1	-0.1	7.0
Oceania	-0.4	0.0	-0.2	-0.2	0.1	7.0
Russia	-0.9	0.0	-1.0	-0.3	-0.2	7.0
Rest of Annex I	-0.2	0.0	-0.1	-0.1	-0.1	7.0
USA	-0.3	0.0	-0.2	-0.3	-0.1	7.0
Brazil	-0.0	0.0	0.1	0.0	0.0	7.0
China	-0.4	-0.1	-0.5	-0.1	-0.3	7.0
India	3.0	0.4	4.8	2.1	0.8	7.0

Indonesia	1.0	0.1	1.4	0.4	0.2	7.0
M. East and N. Africa	0.0	0.0	0.2	0.1	-0.1	7.0
Mexico	0.1	0.0	0.1	0.1	0.0	7.0
South Africa	-0.3	0.0	0.0	-0.1	0.0	7.0
Rest of the world	1.8	0.3	2.1	0.4	0.3	7.0
World	***0.00***	***0.0***	***0.2***		***0.0***	

* Carbon prices in the *450 Per capita* scenario, not deviations from *450 Core*.

** The carbon price in the EU is higher because of the existing EU-ETS.

Note that as all three scenarios investigated here evolve towards equal per capita emissions by 2050, with identical global emission limits, these competitiveness concerns fade away over time. However, as the *450 Delayed Action* scenario requires stronger reductions after 2020, the suboptimal timing of reductions leads to permanently higher global costs; see OECD (2012) for more details.

Tables 3 and 4 present highly aggregated indicators of international competitiveness. Competitiveness losses tend to be concentrated in sub-sectors with very high energy intensity and limited opportunities to pass on additional costs due to trade exposure. The more homogeneous the produced commodity is, the more likely production patters will change geographically. While the CGE modelling framework cannot capture the full details of the output effects at the sub-sectoral level, the following section examines the degree to which output losses are concentrated in EIT sectors and related carbon leakage issues.

3.4. Industry indicators and carbon leakage

To identify more precisely where the largest impacts of international competitiveness are concentrated, we examine sectoral indicators focusing particularly on EIT sectors. In ENV-Linkages, EIT sectors include chemicals, non-ferrous metals, fabricated metal products, iron and steel, pulp and paper, and non-metallic mineral products. Hood (2010) provides a review of how governments have proposed to define EIT sectors that are likely to sustain competitiveness impacts. Clearly, this sectoral analysis is relatively crude, as very specific subsectors cannot be identified. Nonetheless, it does help identify the main areas where competitiveness impacts occur, and is useful in the assessment of the different indicators of competitiveness impacts.

Table 5 shows competitiveness impacts of EIT sector output in the *450 Delayed Action* scenario. There is a clear substitution away from emission-intensive goods such as iron and steel and non-ferrous metals in many OECD Annex I countries. This effect is largest for Canada, Oceania and Japan and Korea across most EIT sectors. For these regions, the EIT sector impacts differ substantially from the regional GDP impacts indicating the relative share changes of EIT sectors are greatest. The smallest effects occur in the EU and EFTA and in the USA. The losses are compounded as a result of changes to their relative competitiveness position and changes to domestic demand. Furthermore, the countries with the largest negative effect on EIT sector output also face the highest carbon prices (see Table 4). EIT sectors in regions that are not bound by targets such as the Middle East and North Africa and the rest of the world countries, mostly experience a relative increase in output. These regions benefit from the fall in competitiveness in regions undertaking climate change mitigation. Regions that undertake relatively weak pledges such as Russia, India and Indonesia also benefit in terms of their relative competitiveness position.

Table 5.Output of EIT sectors in the *450 Delayed Action* scenario, 2020: % change from *450 Core* scenario

Region	Iron and Steel	Non-ferrous metals	Chemicals	Paper and paper products	Fabricated metal products	Non-metallic metals
Canada	-3.4	-9.7	-3.0	-2.2	0.7	-1.9
EU and EFTA	-0.5	-0.1	-0.3	0.0	0.0	-0.4

Japan and Korea	-4.8	-5.5	-3.6	-0.9	-0.7	-2.7
Oceania	-1.6	-13.9	-1.5	0.6	0.6	-1.2
Russia	3.5	3.5	4.4	-1.3	0.2	1.9
Rest of Annex I	1.8	6.1	1.6	0.0	0.4	1.6
USA	-0.1	0.2	-0.4	0.0	-0.2	-0.3
Brazil	-0.1	-0.2	-0.4	-0.1	-0.2	-0.1
China	1.2	1.4	1.4	0.6	0.6	1.3
India	3.1	7.0	1.7	1.9	0.9	1.9
Indonesia	3.0	3.3	1.0	0.9	-0.1	0.7
M. East and N. Africa	1.4	1.0	3.9	0.2	-0.1	0.5
Mexico	-1.0	0.4	-0.4	0.1	0.1	-0.4
South Africa	-3.0	0.6	-1.3	0.0	-1.5	-1.6
Rest of the world	2.8	1.8	0.9	-0.1	-0.1	1.0

In contrast to the *450 Delayed Action* scenario, Table 6 shows little evidence of competitiveness impacts on EIT sector output in the *450 Per capita* scenario. As this scenario assumes a burden sharing regime based on countries receiving a share in global allowances based on projected levels of population, but global emission levels are not affected and there is scope for emissions trading, output in EIT sectors for OECD Annex I countries are largely not reduced: high-cost reduction options are not forced upon domestic sectors as they can participate in the global carbon market and buy permits when these are cheaper than the marginal abatement costs. In some cases, the profit-maximising approach is to reduce relatively polluting domestic production and sell the freed-up permits on the international market. This is projected to occur for some sectors in India and Indonesia.

Table 6.Output of EIT sectors in the *450 Per Capita* scenario, 2020: % change from *450 Core* scenario

Region	Iron and Steel	Non-ferrous metals	Chemicals	Paper and paper products	Fabricated metal products	Non-metallic metals
Canada	0.5	0.8	0.3	0.1	0.3	0.0
EU and EFTA	0.2	0.4	0.1	0.0	0.1	0.0
Japan and Korea	0.2	0.4	0.2	0.0	0.1	0.0
Oceania	0.7	1.4	0.6	0.1	0.4	0.0
Russia	1.3	2.3	0.9	0.8	1.1	-0.1
Rest of Annex I	0.3	0.5	0.2	-0.1	0.2	-0.1
USA	0.7	0.9	0.5	0.1	0.4	0.1
Brazil	0.0	0.1	0.0	0.0	0.0	0.0
China	-0.1	0.1	0.1	-0.1	-0.1	-0.3
India	-2.0	-4.8	-1.9	-0.1	0.3	1.8
Indonesia	-0.8	-1.8	-0.6	-0.8	0.4	0.4
M. East and N. Africa	0.0	0.3	0.1	0.0	0.0	0.0
Mexico	0.1	0.0	0.0	-0.1	-0.1	0.1
South Africa	0.4	0.8	0.4	0.3	0.4	0.1
Rest of the world	-1.0	-2.0	-1.0	-0.3	-0.4	0.6

4 Assessing countervailing policies to address competitiveness impacts of 'Annex I only' mitigation policies[1]

4.1 Overview of 'Annex I only' scenarios to assess competitiveness impacts

In the current political environment, immediate prospects for a globally harmonised carbon market addressing the negative externatility associated with GHG emissions are weak. To meet emission reduction goals pledged under the Copenhagen and Cancún agreements, countries have adopted domestic policy actions. The stylised hypothetical 'Annex I only' 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, and that a new global agreement may not emerge. 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.*, 2011, 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. This hypothetical scenario has a similar policy design to the *450 Delayed Action scenario* as carbon markets are fragmented except only Annex I countries are acting.

The required emission reductions assumed in the *Frag* policy scenario and their interpretation in the modelling framework are summarised in Table 1; 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. It should be stressed that the reason for this assumption is to focus on the competitiveness impacts of a truly fragmented carbon market, not to accurately reflect intended policies or international climate negotiations.

These 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). 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 required 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. Emissions of non-CO_2 greenhouses gases as well as all emissions from agriculture (and 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. 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.

[1] In this section, Japan and Korea are separate regions in ENV-Linkage.

Table 8. 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)	Japan -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	+10% 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 negative competitiveness effects that such a fragmented carbon policy is expected to have on acting countries, three different competitiveness response policies are considered. In order to be able to compare the welfare impacts in each policy simulation, global CO_2 emissions are maintained equal to those the *Frag* policy scenario.

The first response policy considered is the use of border carbon adjustments (*BCAs scenario*), namely 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. Note that, 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. 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.

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). 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 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.[2]

The analysis compares each policy response applied individually as well as a combination of BCAs with direct linking (*Link_BCAs*), indirect linking (*Offsets_BCAs*) and all options together (*All*). Studying these combinations will show whether there is still a case for BCAs in presence of linking. Table 9 summarises the scenarios considered in the analysis. All policy scenarios consider policies implemented starting in 2013 and until 2020.

Table 9. 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_BCAs	Offsets and BCAs
Link_BCAs	Linking and BCAs
All	Linking, offsets and BCAs

4.2. 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 10. 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. These mitigation efforts also have substantial 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 substantially 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

[2] The choice of a project 'baseline' against which certified emission rights (CERs) are granted have an impact on the volume of credits generated and matters for carbon leakage. As in OECD (2009) the reference emission level is set as the emission level in non-Annex I countries when Annex I countries are acting (the Frag scenario). Technically credits are modelled as an output-based rebate together with a carbon tax (with a global price for all non-Annex I countries). The output subsidy is granted by the same sector but in an acting country.

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 (1.3 USD per ton of CO_2) due to the low stringency of the emission target (which is in turn 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. There is a small negative effect on welfare in all regions, except South Africa. This effect is quite strong in the case of energy exporting economies and Russia, where the reduced energy demand in acting regions reduces income from exporting fossil fuels. Benefiting from the fall in competitiveness of energy intensive products in acting countries, production and exports in EIT sectors rise in non-acting countries, especially in Russia, Energy exporting countries, Korea and Indonesia. This also leads to an increase in emissions in most non-acting countries, causing carbon leakage. The leakage rate from acting to non-acting countries is of 8.6% for CO_2 and 4.3% for all GHGs (see Figure 2). [3] 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.

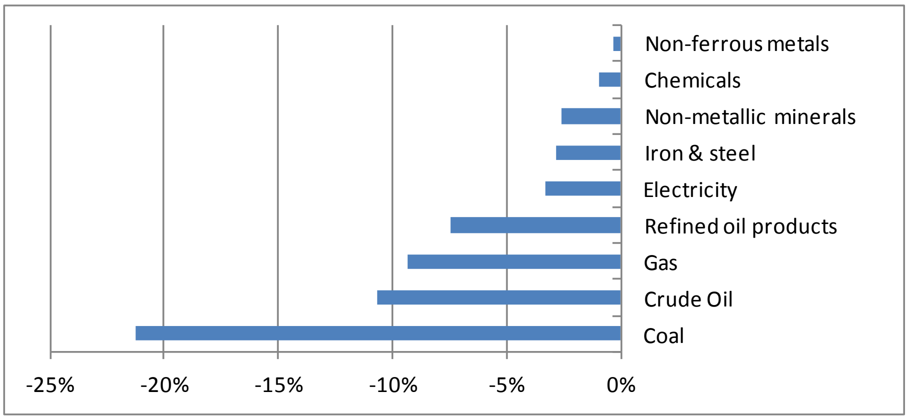
Table 10. Impacts in the fragmented policy scenario on key indicators (% change wrt baseline at 2020)

Region	Welfare	Output (EIT sectors)	Exports (EIT goods)	GHG emissions	Carbon Price
Australia & New Zealand	-0.9	-8.9	-17.3	-16.5	58
Canada	-1.4	-10.2	-12.9	-21.3	94
EU & EFTA	-0.2	-1.3	-1.3	-9.4	54
Japan	-0.4	-5.7	-10.4	-18.6	126
Other European Annex I countries	0.1	2.1	2.7	-0.5	1
USA	-0.3	-3.3	-5.3	-13.9	60
Acting countries	***-0.4***	***-2.7***	***-3.1***	***-10.7***	
Brazil	-0.2	1.8	4.8	0.4	
China	-0.3	0.9	4.1	0.3	
Energy exporting countries	-1.3	3.4	4.7	-0.2	
Indonesia	-0.5	2.7	4.8	0.2	
India	-0.1	1.6	3.2	0.4	
Korea	-0.1	2.5	2.4	0.9	
Mexico	-0.3	1.9	5.6	0.6	
Russia	-1.1	4.9	8.4	0.0	
South Africa	0.0	2.0	4.9	1.1	
Other high and middle income countries	-0.3	2.6	3.0	0.2	
Other low income countries	-0.3	2.4	5.2	0.0	
Non-acting countries	***-0.5***	***1.5***	***3.9***	***0.3***	
World	***-0.4***	***-0.4***	***-0.5***	***-3.8***	

Table 10 provides a macroeconomic view of competitiveness impacts, but as shown in Section 3 above, competitiveness impacts vary substantially across (EIT) sectors. Competitiveness losses tend to be concentrated in sub-sectors with very high energy intensity and limited opportunities to pass on additional costs due to trade exposure. The more homogeneous the produced commodity is, the more production patters 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.

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

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



4.3. Decomposition analysis of the fragmented carbon market scenario

This section presents results of the decomposition analysis to help understand to what extent changes to the design of the fragmented carbon scheme has on competitiveness impacts and carbon leakage rates. The starting point for this analysis is a fragmented scenario where for Annex I countries only, all sources of GHG emissions, sectors and economics agents face a carbon price. It is similar in design and pledges to the stylised scenario described above in section 4.1.The first part of the decomposition analysis considers modifications to the policy design. First it considers the case were all emissions from the agriculture sector (and LULUCF) are excluded from acting countries targets. The second part of the decomposition analysis further restricts the GHG emissions covered by acting countries to only CO_2 emissions from fossil fuel combustion. The last part of the decomposition analysis also exempts households from carbon pricing.

Table 11 outlines the competitiveness impacts and leakage rates for each variant of the decomposition analysis. Where the coverage of emissions facing a carbon price is reduced, as in the scenario where emissions of non-CO_2 greenhouses gases as well as all emissions from agriculture (and LULUCF), and households are assumed to be exempted from carbon pricing (*Frag_No ag_CO_2 only_No HH*), the carbon leakage rate and welfare losses are greatest while world GHG emissions reductions are the lowest. As GHG emissions from sectors and sources are excluded from the scheme, this increases the burden on sectors that are covered under the domestic emission trading schemes in Annex I countries. In contrast, the broader the coverage of the scheme (*Frag*) the higher the world GHG emission reductions and the lower the welfare losses and competitiveness impacts.

Table 11.Decomposition analysis of the fragmented policy scenario on competitiveness indicators (% change wrt baseline at 2020)

Scenario	Leakage Rate (%)	Equivalent Variation in Income			EIT Sector Output			World GHG Emissions
		World	Not-Acting	Acting	World	Not-Acting	Acting	
Frag	3.8	-0.3	-0.5	-0.2	-0.3	-0.3	-0.4	-5.9
Frag_No ag	3.9	-0.3	-0.5	-0.5	-0.3	-0.3	-0.4	-5.8
Frag_No ag_CO_2 Only	5.0	-0.6	-0.8	-0.4	-0.5	-0.3	-0.7	-5.7
Frag_No ag_ CO_2 Only_No HH	6.7	-0.6	-0.8	-0.5	-0.6	-0.5	-0.9	-5.6
Frag_CO_2 Only	5.4	-0.6	-0.8	-0.4	-0.5	-0.3	-0.5	-5.7

The policy decision of which sectors and sources of GHGs to exclude from the design also has implications for competitiveness, welfare and GHG emissions reductions. For example, as a significant proportion of agricultural sector emissions consist of emissions from non-CO_2 GHGs such as methane, the scenario where non-CO_2 emissions are excluded (*Frag_CO_2* only) has similar competitiveness implications world GHG emission reductions as the scenario where agricultural sector emissions are also excluded (*Frag_No ag_CO_2 Only*).

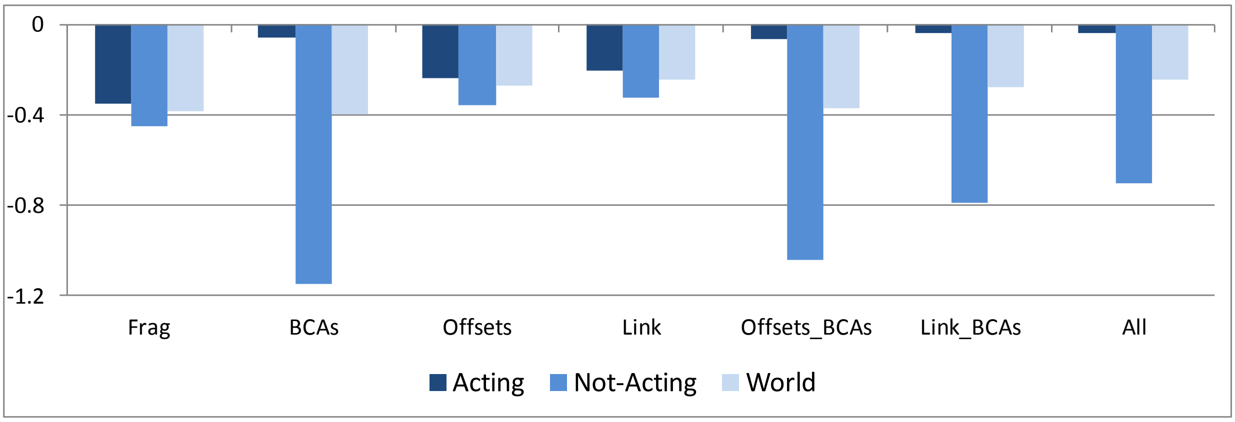
4.4. Comparing response policies in addressing competitiveness issues

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. While in terms of welfare the group of non-acting countries is as heavily affected by the policies as acting countries, these welfare losses are concentrated in the 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 the results are presented here mostly looking at acting and non-acting countries in aggregate, tables in Annex 2 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. A key assumption is that the acting countries aim at the same level of global emission reductions in all scenarios, and thus reduce their domestic mitigation efforts when they apply a BCA or use offsets. However, welfare decreases substantially 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.

Compared to BCAs, linking is more equitable: both acting and non-acting countries benefit from the implementation of linking. Direct linking is slightly superior to indirect linking (offsets) in improving welfare impacts, especially in acting countries, although this result depends on the level of offsets allowed in the *Offsets* scenario. 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 still substantially reduce global welfare losses when combined with BCAs, the global benefits from offsets when combined with BCAs are smaller. This is due to the substantial 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 (% change wrt baseline at 2020)



Concerns for acting countries are particularly focused on EIT sectors as these suffer the highest output, trade and competitiveness losses, as illustrated in Table 11. 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. As 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 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 competitiveness of EIT sectors in acting countries. Linking instruments also reduce the competitiveness losses 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 positive effects of the fragmented climate policy on EIT sectors in non-acting countries persist in the case of linking, although the benefits are reduced.

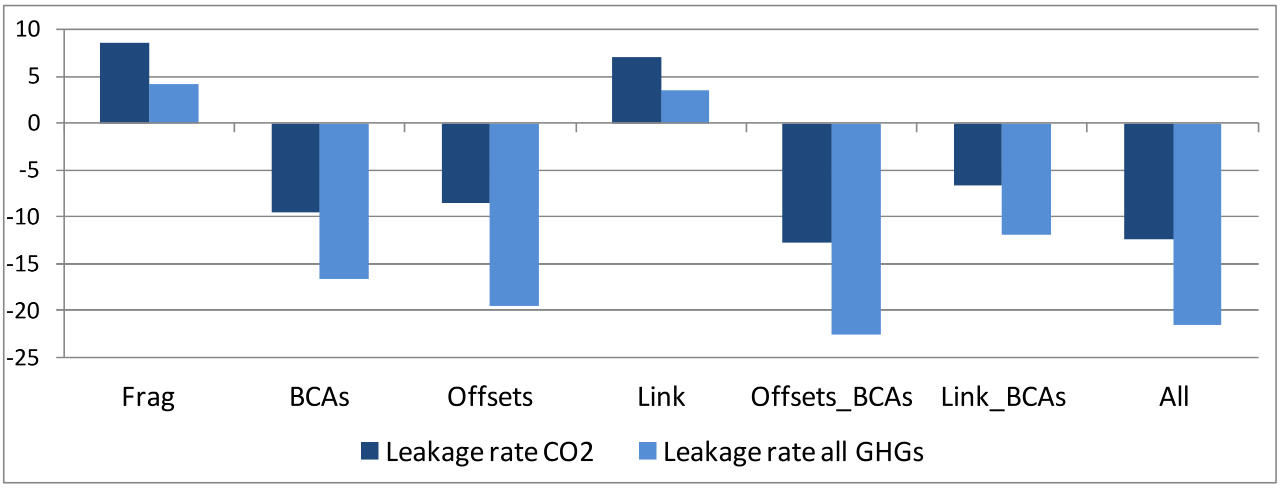
While all climate policies have a negative impact on global output, there is a strong difference in the regional distribution of cost across the scenarios. In the presence of BCAs both acting and non-acting countries face small output losses, while in the absence of BCAs, acting countries encounter output losses and non-acting countries increase their output though not sufficiently to maintain world output unchanged. Global output losses are smallest in the case in which all response policies are implemented. The multiplicity of instruments helps industries face the burden of the climate policy.

Table 12. Competitiveness impacts of response policies in EIT sectors (% change wrt baseline at 2020)

	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_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

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, leading to carbon leakage. This leakage effect can be modified with the implementation of the response policies, as illustrated in Figure 3. BCAs can re-establish production patterns and not only eliminate the carbon leakage effect but even lead to a negative leakage rate. This happens when emissions are reduced not only in acting but also in non-acting countries. Offsets can also lead to a negative leakage rate as they encourage emission reductions in non-acting countries. On the other hand, 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 their competitive position.

Figure 3. World leakage rate under the different response policies (% change wrt baseline at 2020)[4]



The alternative policies have different effects on carbon prices. As illustrated in Table 12, 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. Combining offsets and BCAs does not lower carbon prices further than only having offsets. 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. Direct linking substantially reduces carbon prices for all 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 towards the other acting regions. The implementation of linking with other instruments further diminishes the carbon price, showing that in this case the multiplicity of instruments has a positive effect on the carbon market.

Table 12. Carbon prices in acting countries in the different response policies (USD 2010 / ton of CO_2)

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

5. Conclusions

The recent and ongoing climate change negotiations suggest that at least in the short run, 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 about domestic welfare, output losses of

[4] 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.

energy-intensive industries, and carbon leakage. This paper first assesses the national and sectoral competitiveness impacts of global mitigation policies, and next analyses the effectiveness of border carbon adjustments (BCAs) and direct and indirect linking as means to level carbon prices across countries, to reduce carbon leakage and output and competitiveness losses. 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 global mitigation scenarios presented illustrate varying degrees of competitiveness losses. For the macroeconomic and industry indicators outlined, competiveness impacts are largest in the scenario where carbon markets are not linked and pledges vary. Global mitigation scenarios with harmonised carbon markets and burden sharing permit allocation rules display minimal competitiveness impacts despite greater reductions in GHG emissions than fragmented carbon market scenarios.

Second, the simulation results illustrate that a fragmented climate policy can lead to substantial 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, decreasing 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.

Third, the decomposition analysis of the fragmented carbon market scenario illustrates that the greater the restrictions on sectors, sources of GHG and economic agents covered by the domestic ETS, the higher the competitiveness implications and welfare losses and lower the reductions in world GHG emissions. The policy decision to exclude certain combination of sectors and sources of GHG emissions also has implications for welfare, competitiveness impacts and reductions in world GHG emissions.

Fourth, 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 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 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.

One important caveat to these assessments is that they assume idealised policy instruments with frictionless markets. 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 offset mechanism that is modelled here is perhaps the most sensitive to these market imperfections and therefore the most idealised representation of the instruments investigated in this paper.

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.

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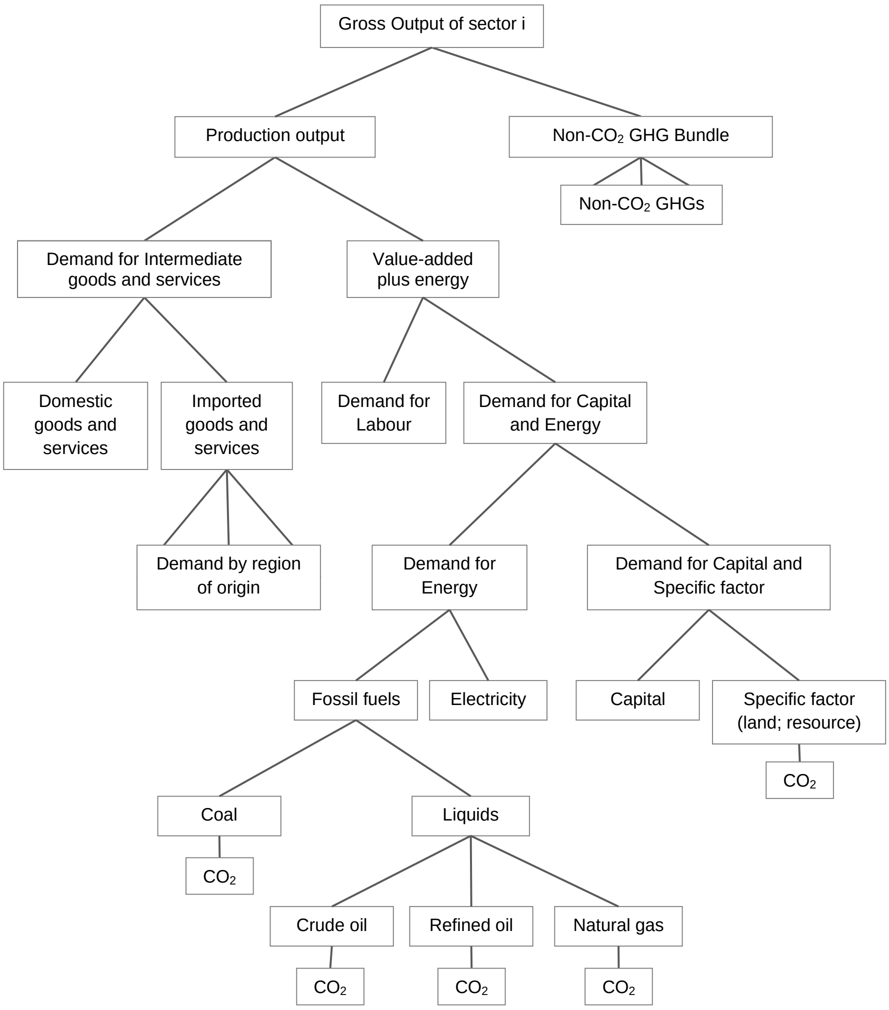
ANNEX 1: Production structure of a generic (non-agriculture and non-energy) sector in ENV-Linkages



ANNEX 2: Regional results

Table A2.1. Impacts of response policies on welfare by region (% change wrt baseline at 2020)

Region	Frag	BCAs	Offsets	Link	Offsets_BCAs	Link_BCAs	All
Australia & New Zealand	-0.89	-0.40	-0.58	-0.09	-0.40	0.04	0.02
Canada	-1.43	-0.94	-0.99	-0.76	-0.94	-0.59	-0.53
EU & EFTA	-0.20	0.06	-0.13	-0.08	0.06	0.11	0.10
Japan	-0.39	0.08	-0.22	-0.35	0.08	-0.16	-0.14
Other European Annex I countries	0.14	0.14	0.11	1.96	0.14	1.59	1.42
USA	-0.31	-0.02	-0.18	-0.34	-0.02	-0.15	-0.13
Acting countries	-0.35	-0.05	-0.22	-0.20	-0.05	-0.04	-0.03
Brazil	-0.18	-0.40	-0.15	-0.14	-0.40	-0.32	-0.28
China	-0.25	-1.35	-0.20	-0.12	-1.35	-0.99	-0.84
Energy exporting countries	-1.34	-1.82	-1.04	-1.07	-1.82	-1.49	-1.32
Indonesia	-0.48	-0.76	-0.38	-0.29	-0.76	-0.53	-0.46
India	-0.06	-0.61	-0.05	-0.01	-0.61	-0.51	-0.43
Korea	-0.05	-0.20	-0.02	0.03	-0.20	-0.09	-0.07
Mexico	-0.26	-0.34	-0.20	-0.18	-0.34	-0.27	-0.24
Russia	-1.15	-1.15	-0.89	-0.15	-1.15	-0.35	-0.30
South Africa	0.03	-0.46	0.01	0.04	-0.46	-0.37	-0.31
Other high and middle income countries	-0.26	-0.68	-0.20	-0.23	-0.68	-0.55	-0.48
Other low income countries	-0.32	-0.79	-0.23	-0.23	-0.79	-0.57	-0.49
Non-acting countries	-0.45	-1.03	-0.35	-0.32	-1.03	-0.79	-0.68
World	-0.38	-0.36	-0.26	-0.24	-0.36	-0.27	-0.24

Table A2.2. Impacts of response policies on EIT sectors' output by region (% change wrt baseline at 2020)

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

Table A2.3. Impacts of response policies on EIT goods' exports by region (% change wrt baseline at 2020)

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

Table A2.3. Impacts of response policies on EIT sectors' imports by region (% change wrt baseline at 2020)

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