

The Role of Border Carbon Adjustment in Unilateral Climate Policy

Insights From An EMF Model Comparison

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Abstract

Issues of emission leakage and competitiveness are at the fore of the climate policy debate in all the major economies implementing or proposing to implement significant emissions cap-and-trade programs. Unilateral climate policy cannot directly impose emissions prices on foreign sources, but it can complement domestic emissions pricing with border carbon adjustment to reduce leakage and increase global cost-effectiveness. While border carbon adjustment has a theoretical efficiency rationale, its practical implementation is subject to serious caveats. This model comparison study assesses the efficiency and distributional impacts of border carbon adjustment. We find that border carbon adjustment can effectively reduce leakage and ameliorated adverse impacts on energy-intensive and trade-exposed industries of unilaterally abating countries. However, the scope for global cost savings is limited. The main effect of border carbon adjustment is to shift the economic burden of emission reduction to non-abating countries through implicit changes in international prices.

1. Introduction

Given the bleak prospects for a global agreement on collective greenhouse gas reduction, individual industrialized countries are pushing for unilateral climate policy in the hope that other countries will follow suit. The fundamental drawback with unilateral action to combat the global greenhouse gas externality is that it forgoes large cost savings from where-flexibility (Weyant 1999): To minimize abatement cost, emissions should be reduced where it is cheapest world-wide. With unilateral emission constraints, marginal abatement cost in countries without emission control are zero indicating a huge but unexploited potential for cost savings.

Beyond the lack of globally coordinated abatement action, unilateral climate policy faces additional challenges which can be traced back to international market responses. Emission constraints in an

open economy not only cause structural adjustment of domestic production and consumption but also affect comparative advantage which drives the pattern of international trade through relative cost differences between countries. As a consequence, the global cost-effectiveness of unilateral emission reduction can be hampered by so-called emission leakage, i.e., the relocation of emissions to parts of the world economy subject to no (or weaker) regulation. There are two major intertwined channels for leakage which capture international spillovers from fossil fuel markets on the one hand and from non-energy markets on the other hand. Leakage through the fossil-fuel-price channel occurs as reduced energy demands of emission-constrained regions depress international fuel prices, which in turn triggers additional energy demand and emissions in unconstrained countries. Leakage through the competitiveness-channel on non-energy markets occurs as energy-intensive and trade-exposed (EITE) industries of unilaterally abating countries face higher cost compared to international rivals which incentivizes the relocation of these industries abroad. The latter channel amplifies adverse production and employment impacts of EITE industries in unilaterally regulating countries.

Concerns on environmental effectiveness and the competitiveness of EITE industries are at the fore of the climate policy debate in all the major economies implementing or proposing to implement emissions reduction measures. In response to such concerns, border carbon adjustment (BCA) appeals as a policy option for many countries that intend to move forward with unilateral climate policies. Unilateral policies cannot directly impose emission prices on foreign sources, but it can complement domestic emissions pricing with BCA to reduce leakage and increase global cost-effectiveness. On the import side, emissions embodied in imported goods and services from non-regulating countries should be taxed at the emission price of the regulating region. On the export side, emission charges paid by domestically regulated firms are rebated for exports to non-regulating countries. If comprehensively applied, BCA effectively works as destination-based carbon pricing which level the playing field in international trade while internalizing the cost of climate damage into prices of goods and services.

While BCA has theoretical appeal on global efficiency grounds (Markusen 1975, Hoel 1991), it may be rather controversial with respect to induced distributional impacts. BCA provides scope for back-door trade policy since it can work as a substitute for strategic tariffs shifting the economic burden of emission reduction from abating countries to non-abating countries (Böhringer, Carbone and Rutherford 2011). The burden shifting potential of BCA may accommodate strategic leverage to trigger cooperation by non-abating countries but the coercive nature can also backfire and lead to detrimental trade conflicts.

In this overview paper, we summarize results from a model-comparison study to assess the efficiency and distributional impacts of BCA addressing the subsequent key policy questions:

- How effective is BCA in reducing carbon leakage?
- Is BCA an effective tool for the protection of EITE industries in unilaterally abating regions?

- How big are the global cost savings from BCA?
- What is the incidence of BCA across regions?

To answer these questions, the study builds on model-based analysis of twelve expert groups that jointly investigate a set of pre-defined policy scenarios with harmonized assumptions and a common dataset. Furthermore, each expert group complements the joint assessment with additional specific insights on the role that BCA can play in unilateral climate policy.

Table 1 gives a summary of the groups involved in the model study, their models in use, and their specific research contribution.

All models included in the analysis are multi-sector, multi-region computable general equilibrium (CGE) models which constitute a wide-spread analytical framework for the impact assessment of climate policies. CGE models build upon general equilibrium theory that combines assumptions regarding the optimizing behavior of economic agents with the analysis of equilibrium conditions: Producers employ primary factors and intermediate inputs at least cost subject to technological constraints; consumers maximize their well-being subject to budget constraints and preferences. CGE analysis provides counterfactual ex-ante comparisons, assessing the outcomes of policy reforms with what would have happened had it not been undertaken (the so-called business-as-usual). The main virtue of the CGE approach is its comprehensive representation of market interactions through price- and income-responsive supply and demand reactions. Beyond price-induced structural change in production and consumption, CGE models can quantify efficiency implications and distributional impacts of policy measures.

As to the representation of international trade which is central to our assessment of leakage and competitiveness impacts all but one model in the cross-comparison adopt the Armington assumption of product heterogeneity (Armington 1969) for all traded goods. Changes in trade are explained through relative cost changes between countries – in our case triggered by unilateral emission regulation. One model incorporates more recent findings in trade theory (Melitz 2003) to explain trade pattern through productivity differences across heterogeneous firms. The intra-industry reallocations of market shares and productive resources between heterogeneous firms add to effects associated with inter-industry reallocations that are driven by comparative advantage. As to data, all models make use of the GTAP 7.1 database which includes detailed national input-output tables on production and consumption together with bilateral trade flows and CO₂ emissions for up to 112 regions and 57 sectors in the year 2004 (Narayanan and Walmsley 2008).

Our overview proceeds as follows. Section 2 lays out the study design. Section 3 discusses the key findings of the twelve models included in the cross-comparison. Section 4 reviews the additional insights from individual analysis of BCA issues. Section 5 concludes.

Table 1: Expert teams participating in the cross-model comparison

Model	Institution	People	Specific paper contribution to Special issue
BCR	Universities of Oldenburg, Calgary, and Wisconsin (Madison)	Böhringer, Carbone, Rutherford	Unilateral climate policy design: efficiency and equity implications of alternative instruments to reduce carbon leakage
CEPE	ETH Zürich	Caron	Estimating carbon leakage and the efficiency of border adjustments in general equilibrium - does sectoral aggregation matter?
DART	Kiel Institute for the World Economy (IfW), Kiel	Hübler, Peterson, Weitzel	Fair, optimal or detrimental? Environmental vs. strategic use of border carbon adjustment
CVO	University of Oldenburg	Springmann	A look inwards: carbon tariffs versus internal improvements in emissions-trading systems
EC-MS-MR	Environment Canada, Ottawa	Gosh, Luo, Siddiqui, Zhou	Border tax adjustments in the climate policy context: CO ₂ versus broad-based GHG emission
ENV-LINKAGES	OECD, Paris	Chateau, Dellink	Alternative approaches for leveling carbon prices in a world with fragmented carbon markets
FF	International Trade Commission (ITC), Resources for the Future (RFF), Washington	Fischer, Fox	Climate policy and fiscal constraints: Do tax interactions outweigh carbon leakage?
MINES	Colorado School of Mines, Golden, University of Wisconsin, Madison	Balistreri, Rutherford	Subglobal Carbon Policy and the Competitive Selection of Heterogeneous Firms
PACE	Centre for European Economic Research (ZEW), Mannheim	Alexeeva-Talebi, Böhringer, Löschel, Voigt	The value-added of sectoral disaggregation: implication on competitive consequences of climate change policies
SNOW	Statistics Norway, Oslo	Böhringer, Bye, Faehn, Rosendahl	Alternative designs for tariffs on embodied carbon: a global cost-effectiveness analysis
WEG_CENTER	University of Graz	Bednar-Friedl, Schinko, Steininger	The relevance of process emissions for carbon leakage: A comparison of unilateral climate policy options with and without border carbon adjustment
WORLDSCAN	Central Planning Bureau (CPB), Den Haag	Boeters, Bollen	Fossil fuel supply, leakage and the effectiveness of border measures in climate policy

2. Study design

The primary objective of our cross-model comparison is to investigate the economic impacts of BCA as a complementary instrument to domestic climate policy. The economic rationale for BCA is to counteract efficiency losses of unilateral abatement that emerge from international feedback effects.

Without international market responses, unilateral abatement would not be hampered on environmental grounds – domestic abatement would translate one-on-one to global emission reduction. In this case, efficient unilateral contribution to the global public good boils down to uniform emission pricing across all sources of the domestic economy (assuming that there are no other initial distortions) which can be implemented through a common emission tax or likewise a cap-and-trade system. In our study, such uniform emission pricing constitutes the reference unilateral climate policy design (scenario label *ref*) against which we compare the imposition of additional BCA (scenario label *bca*). If unilateral reduction covers several sovereign countries within an abatement coalition, we assume identical emission reduction targets (relative to the respective business-as-usual emission levels) which can be traded across all members of the abatement coalition.

Accounting for international feedback effects, BCA qualifies in theory as a second-best instrument which complements uniform domestic emission pricing. Import tariffs should mimic the domestic emission price on the carbon content of all goods that are not regulated in the countries of origin. Likewise, payments for emissions embodied in exports to non-regulated countries should be rebated. In policy practice, however, such a comprehensive BCA system appears rather unrealistic – desirability and feasibility of BCA depend on legal, practical and political considerations that must be balanced against the theoretical potential for efficiency gains.

The policy-relevant design of BCA requires concretization along several dimensions which apply as the default for the central case simulations of our cross-model comparison:

- Sector coverage: We limit the application of BCA to EITE industries that are considered as most vulnerable to leakage through the competitiveness channel.
- Embodied carbon coverage: As to the accounting of emissions embodied in the production of imported goods, we only consider direct emissions from the combustion of fossil fuels and indirect emissions associated with the generation of electricity. Multi-region input-output calculations based on empirical data suggest that indirect emissions from electricity cover the bulk of total indirect emissions (Böhringer, Carbone and Rutherford 2011).¹
- Tariff rate differentiation: We take carbon flow information provided by GTAP to determine country- and sector-specific carbon coefficients.

¹ Note that the carbon metric in our central case simulations does neither include process-based CO₂ emissions nor other non-CO₂ greenhouse gases.

- Inclusion of export rebates: True destination-based carbon pricing calls for rebates, i.e., exports from regulating countries are relieved of the burden of the carbon payments associated with their production. Export rebates contribute to the cost-effectiveness of BCA since they avoid leakage from losing market shares in foreign markets. On the other hand, export rebates may constitute a subsidy under the WTO's Agreement on Subsidies and Countervailing Measures (Cosbey et al 2012). To assess the full efficiency potential of BCA, our central case simulations refer to full border adjustment, i.e., the combination of import tariffs and export rebates. In the sensitivity analysis, we investigate how important the inclusion of export rebates is as we compare full BCA with the case of import tariffs only.
- Use of revenues from import adjustments: By default, we assume that revenues from BCA tariffs are directed to the general revenues of the collecting (abating) country. Another policy-relevant option, which directly affects the distributional impacts of BCA, is to hand back import tariffs to the exporting country – we consider this variant in our sensitivity analysis.

Emission leakage and thus the relative importance of BCA as a complementary anti-leakage measure hinges crucially on the size of the abatement coalition and the coalition's emission reduction target. *Ceteris paribus* leakage will be the more pronounced the smaller the coalition size and the lower the emission reduction target. For our central case simulations, we assume that industrialized countries as listed in Annex 1 of the Kyoto Protocol² –including the United States of America but without the Russian Federation³ – take a lead in unilateral climate action. This abatement coalition (subsequently referred to as A1xR) agrees on a collective 20 % emission reduction from its historical emission level in 2004 which constitutes the base year of the GTAP7.1 dataset; the collective target is spread equally (in relative terms of 20 %) across all members of the abatement coalition. The magnitude of the reduction target roughly reflects post-Kyoto reduction pledges of Annex 1 countries based on national communications following the 15th Conference of Parties (to the United Nations Framework Convention on Climate Change – UNFCCC) at Copenhagen in 2009. The reduction pledges are given for most Annex 1 countries with respect to historical emission levels in 1990 or 2005 but apply to 2020. As a consequence, the business-as-usual development for emissions will determine the effective emission reduction requirements. The higher the future business-as-usual emission levels, the more stringent are the effective reduction targets and thus the potential cost of climate policy. Given larger uncertainties in business-as-usual projections – not at least implicit to the global economic turmoil since 2008 – we decided to use the 2004 (data) base year also as the target year for emission abatement. While this assumption at first glance might lack policy appeal, it strengthens the coherence of the cross-model comparison since there is no need for model re-parameterization to controversial business-as-usual projections on macroeconomic growth and structural changes. Using the same

² See http://unfccc.int/parties_and_observers/parties/annex_i/items/2774.php

³ The reason to exclude Russia is that larger fuel exporting countries are rather opposed to climate policies since they fear substantial losses in their export revenues.

empirical data across all the models, we can focus on microeconomic cause-effect chains of emission regulation without overlapping “noise” from business-as-usual calibrations to future – rather hypothetical – data. The business-as-usual scenario (thereafter labeled *bau*) against which we measure the impacts of unilateral climate policies (*ref* and *bca*) in our central case simulations is therefore the historical economic situation in 2004. On the other hand, we acknowledge the policy interest in economic impact assessment of regulation that applies to future years and therefore investigate in the sensitivity analysis the implications of a shift in the target year to 2020.⁴ Another dimension of our sensitivity analysis is to check the robustness of results with respect to changes in the coalition size.

In order to assure a coherent cross-comparison, all models in the study adopt a minimum level of sectoral and regional disaggregation which reflects the specific requirements of BCA assessment and the empirical data provided by GTAP database. The harmonized composite dataset includes all major primary and secondary energy carriers: coal, crude oil, natural gas, refined oil products, and electricity. This disaggregation is essential in order to distinguish energy goods by CO₂ intensity and the degree of substitutability. In addition, all EITE sectors of the GTAP database are accounted for: chemical products, non-metallic minerals, iron and steel products, and non-ferrous metals. These four sectors together with oil refineries are most vulnerable to unilateral emission constraints and therefore are prime candidates for protective BCA; in the remainder of the study we refer to the composite of the five energy-intensive and trade-exposed sectors as EITE industries. Regarding regional coverage, the composite dataset includes all major industrialized and developing countries in order to adequately capture international market responses to unilateral emission regulation. Table 2 summarizes the minimum set of explicit sectors (commodities) and regions that are included across all models participating in the cross-comparison.

Given the uncertainty of external cost estimates for carbon emissions, the consistent comparison of alternative unilateral climate policy designs implies a cost-effectiveness approach where we keep global emissions constant. In other words: Without quantification of emission damages, welfare comparisons only make sense between scenarios with identical global emission levels where the gross benefit of abatement across all regions is the same. For all policy simulations, the global emission constraint is set to achieve an effective emission reduction equal to the 20 % emission pledge of the abatement coalition. The global emission constraint requires that the initial emission cap of the abating coalition is scaled endogenously to compensate for emission leakage which already applies to the reference scenario without BCA. In this framework, leakage reduction through BCA implies that unilaterally abating regions must cut back domestic emissions to a lesser extent than in the reference scenario in order to meet the global emission constraint.

⁴ The study provided information sources for official baseline projections such as the International Energy Outlook but there had been no binding provisions on the business-as-usual in 2020.

Table 3 summarizes the key design elements for the central case simulations of the model cross-comparison.

Table 2. Sectors and regions explicitly included in the model cross comparison

<i>Sectors and commodities</i>	<i>Countries and regions</i>
<i>Energy goods</i>	<i>Annex 1 (industrialized) regions</i>
Coal	Europe – EU-27 plus EFTA **
Crude oil	USA – United States of America **
Natural gas	Russia
Refined oil products *	Remaining Annex 1 (RA1)**
Electricity	
	<i>Non-Annex 1 regions</i>
<i>Non-energy goods</i>	China
Chemical products *	India
Non-metallic minerals *	Energy exporting countries excl. Mexico (EEX)
Iron and steel industry *	Other middle income countries (MIC)
Non-ferrous metals *	Other low income countries (LIC)
Transport	
All other goods	

*Included in the composite of *energy-intensive and trade-exposed* (EITE) industries **Included in the composite region A1xR

Table 3. Basic features of unilateral climate policy design

Size of the abatement coalition	A1xR – all Annex 1 regions (including the USA but without Russia)
Emission reduction target	20 % from historical 2004 levels
Default unilateral climate policy (<i>ref</i>)	Each abating region adopts a uniform 20 % target which can be traded across abating regions.
Imposition of complementary BCA (<i>bca</i>)	<ul style="list-style-type: none"> - Import tariffs plus export rebates - Sector coverage: EITE industries - Embodied carbon coverage: direct emissions plus indirect emission from electricity - Import tariffs accrue to importing regions
Constant global emission constraint	<i>bau</i> emissions of non-coalition countries plus 80 % (= 100%-20%) of coalition countries' <i>bau</i> emissions

3. Common results

Economic impacts of regulatory policies (*ref* and *bca*) are reported with respect to the business-as-usual where no explicit climate policy applies. Thus, we can not only quantify how complementary BCA changes the outcome of the reference climate policy but we also obtain policy-relevant information on the overall adjustment cost of emission regulation compared to the business-as-usual situation without climate policy (*bau*). As a matter of fact, the international policy debate is dominated by the issue of burden sharing given the short-term nature of abatement cost and the long-term nature

of (more uncertain) benefits from emission reduction.⁵ Note that the business-as-usual benchmark helps to figure out how important the implications of additional BCA are with respect to overall economic adjustment triggered by emission constraints.

While the multi-sector, multi-region structure of CGE models allows for the detailed impact analysis at the level of individual sectors and regions our primary interest is on how BCA affect global efficiency of unilateral climate policy, the incidence on the average abating region versus the average non-abating region, as well as the implications for the average EITE industry. We define two additional composite regions: “coa”, the aggregate of coalition regions with unilateral emission regulation, and “ncoa”, the aggregate of non-coalition regions without emission regulation. These labels will show up in the graphical and tabular results presentations below. Beyond the explicit reference to model-specific results using the model acronyms as defined in Table 1, we provide mean results (labeled “mean”) across all models. As the default, we order simulation results by ascending order of the reference scenario’s (*ref*) impacts.

3.1. Leakage rates, CO₂ emissions, CO₂ prices, and EITE output effects

Fig. 1 shows the impacts of unilateral climate policy on leakage rates as a key environmental indicator of international feedback effects.

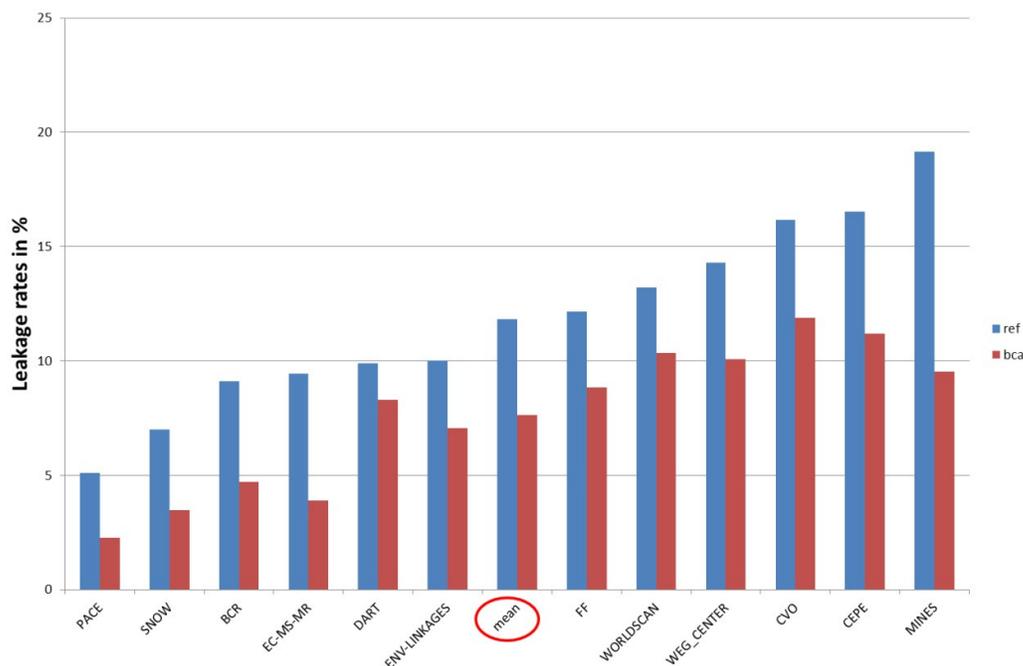


Fig. 1 Leakage rates (in %)

⁵ Abstracting from benefits of emission abatement in our analysis, gross welfare changes from the business-as-usual can serve at least as a lower bound estimate for the benefits of emission abatement that would justify abatement action from the perspective of a more comprehensive cost-benefit analysis.

The leakage rate is defined as the change in foreign (non-coalition) emissions over domestic (coalition) emission reduction. A leakage rate of 50 %, for instance, means that half of the domestic emission reduction is offset by increases in emissions abroad. The higher the leakage rate in the reference scenario with uniform emission pricing only, the more important becomes complementary BCA to reduce leakage under global cost-effectiveness considerations.

In the reference scenario, leakage rates range between 5-19 % with a mean value of 12 %. Given that the size of the abatement coalition and its reduction target have been harmonized across all models, differences in leakage rates can be primarily traced back to model-specific assumptions on the degree of fossil fuel supply responses and the heterogeneity in traded goods. Heterogeneity of traded goods is captured through the choice of Armington elasticities that determine the ease of substitution between domestic goods and imported (exported) goods of the same variety. The higher the Armington elasticities, the stronger is leakage through the competitiveness channel as regions can more easily substitute to new sources for EITE goods in response to the changes induced by the climate policy regime. Supply responses of fossil fuel producers are captured through fossil fuel supply elasticities. The lower these supply elasticities are, the higher is leakage through the fossil fuel channel as the decreased demand for fossil fuels in abating regions produces larger reductions in the price of these goods on world markets.

BCA is effective in reducing leakage. Leakage rates under BCA range between 2-12 % with a mean value of 8 %. Thus, the carbon-based import tariffs and export rebates to EITE products reduce the leakage rate on average by a third compared to the reference scenario with uniform emission pricing only.

The leakage-reduction effect of BCA directly shows up in the aggregate emission reduction requirements for the composite of abating and non-abating regions (cf. Fig.2). Under BCA the abatement coalition can scale down its domestic emission requirement to achieve the given global emission reduction target.⁶ On global cost-effectiveness grounds, BCA helps to re-allocate emissions between the abating and non-abating countries in the “right” (cost-saving) direction. Yet, it should be clear that BCA is only a blunt second-best instrument as overall emissions in non-abating countries are still above the *bau* level and far off from a first-best outcome that would be achieved through a global cap-and-trade system.

⁶ Drawing on the GTAP data for 2004, the 20 % emission reduction pledge of the A1xR abatement coalition corresponds to a 9.5 % reduction of global emissions which equally applies to the *ref* and *bca* scenarios.

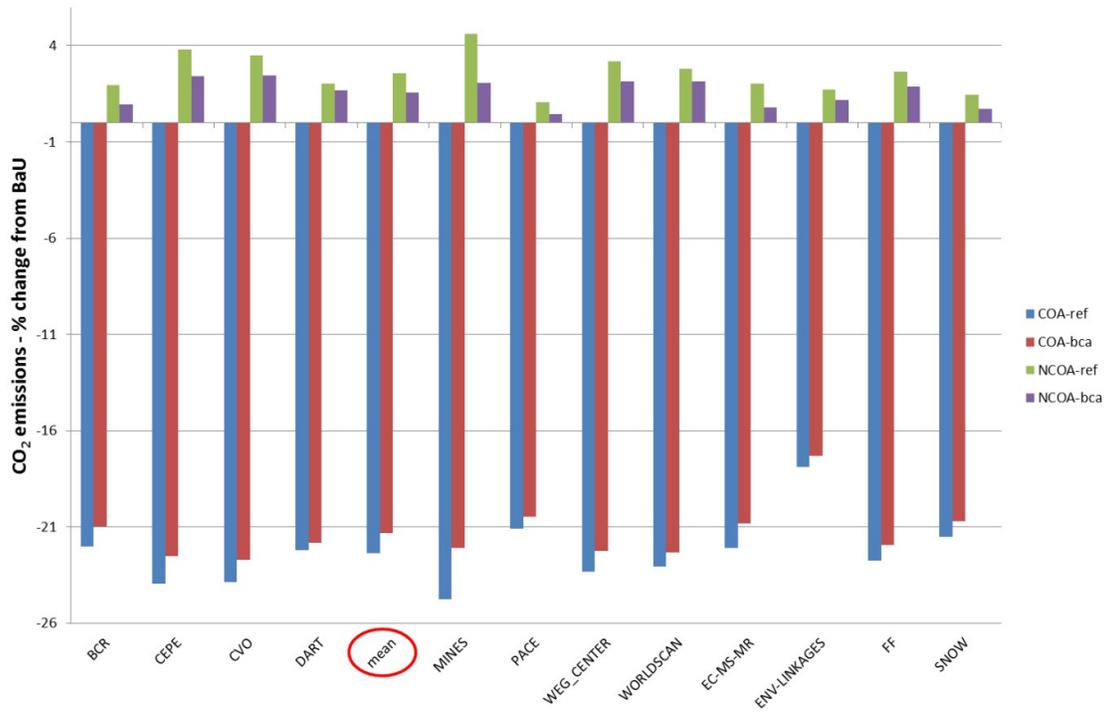


Fig. 2 CO₂ emissions in abating (COA) and non-abating regions (NCOA) – % change from *baU*

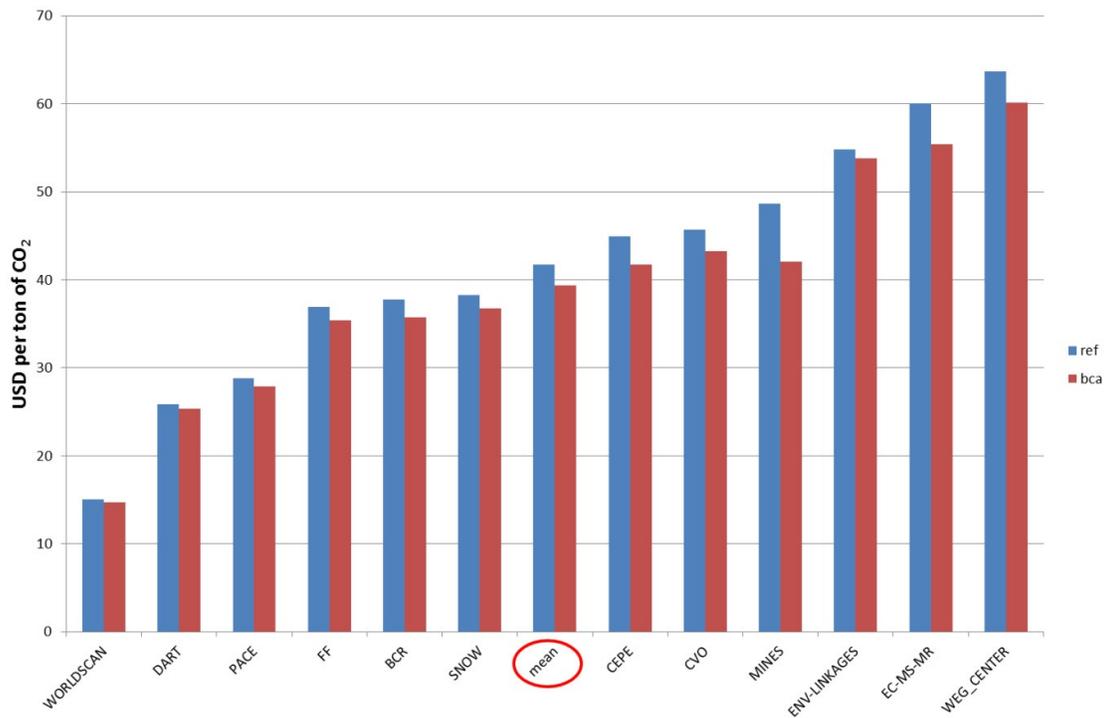


Fig. 3 CO₂ prices (USD per ton of CO₂)

Marginal abatement cost in coalition countries for the reference scenario reveal a substantial spread across the different models ranging from 15 to 60 USD per ton of CO₂ with an average of around 40 USD per ton of CO₂ (cf. Fig.3). The variation is due to differences in the ease of carbon abatement across models. Effectively, there are three canonical options to reduce carbon in production and consumption: fuel switching (such as replacing coal-fired power plants through gas-fired power plants), energy efficiency improvements (such as substituting capital for energy in more energy-efficient air conditioning) or scale reduction in the production and consumption of energy-intensive goods. In an open economy, substitution can also take place through shifting to EITE products from unregulated countries (resulting in positive leakage if competing goods from abroad are more emission-intensive). All these abatement options are typically explicit in bottom-up representations of marginal abatement cost curves but implicit in top-down models based on continuous functional forms to characterize technologies on the production side and preferences on the consumption side through nested separable constant-elasticity-of-substitution (CES) cost and expenditure functions. The nesting of different inputs and the ease of cross-price substitution as captured through CES elasticities should reflect empirical evidence but there is a broader range of sector- and region-specific empirical estimates that qualify for model parameterization. *Ceteris paribus*, lower CO₂ prices in our comparative study indicate that the respective models postulate cheaper carbon abatement options, i.e., a flatter marginal abatement cost curve.

The implementation of BCA slightly reduces the marginal abatement cost compared to the *ref* scenario as the effective reduction requirement for abating countries is lower. Again, it becomes clear that BCA is only a weak instrument to improve on the global inefficiency of unilateral action. Marginal abatement cost in unregulated countries are still zero – tariffs applied to the sector-average of embodied carbon are far off from working as effective pricing of emission inputs in non-abating countries.

Competitiveness concerns of regulated EITE industries are central to the policy debate on unilateral climate policies. Unilateral emission pricing of industries where emission-intensive inputs represent a significant share of direct and indirect cost puts these sectors at a disadvantage with international competitors. For the reference scenario, all models indicate output losses of EITE industries in the abating regions whereas EITE industries in non-abating countries increase production beyond *bau* levels (see Fig.4).⁷ BCA levels the playing field in international trade of EITE commodities – the loss of EITE production in abating countries falls on average from 2.8 % to roughly 1 %; BCA thus constitutes an effective instrument for maintaining competitiveness of EITE industries.

⁷ The competitiveness effects of unilateral action for EITE industries are most pronounced in the MINES model that accounts for firm heterogeneity and endogenous productivity shifts.

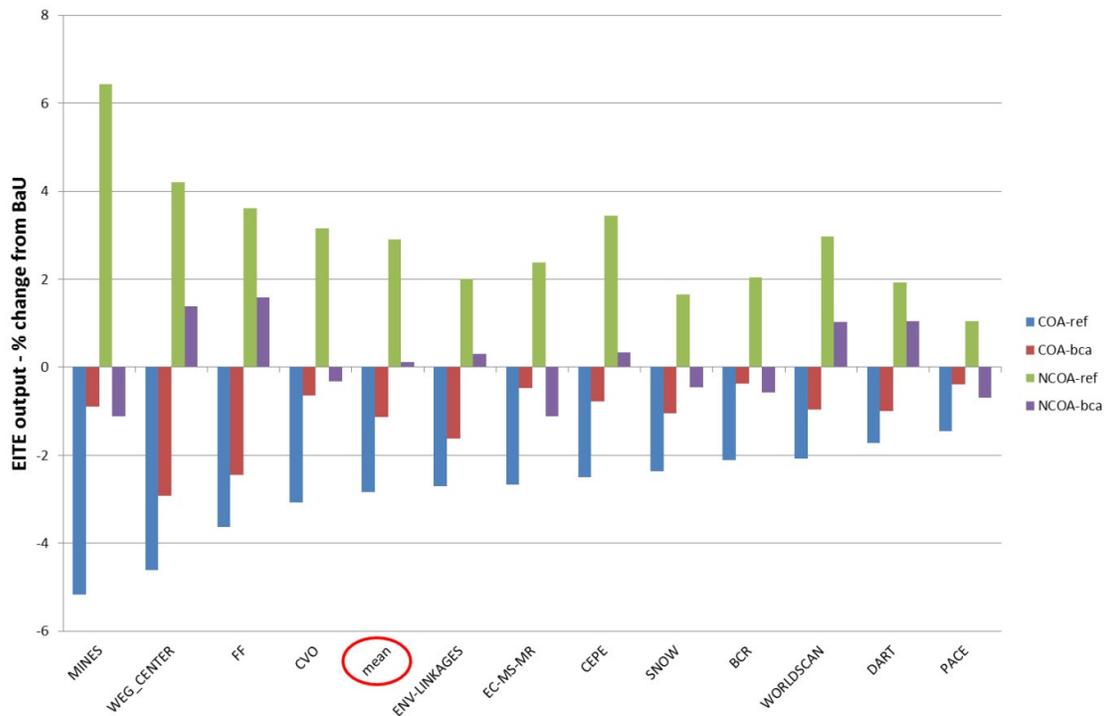


Fig. 4 Output of EITE industries in coalition and non-coalition countries (% change from *bau*)

3.2. GDP impacts – efficiency and incidence

Fig. 5 reports macroeconomic impacts in terms of global changes in the gross domestic product (GDP). The key message is that adjustment to achieve a global emission reduction by roughly 10 % through unilateral abatement action of A1xR countries cause relatively moderate GDP losses that range between 0.13 % - 0.63 % with a mean value of 0.35 %. The second message is that BCA improves on global cost-effectiveness of unilateral action but the cost savings vis-à-vis the reference policy are quite limited.⁸ Compared to the global GDP loss in the reference scenario the BCA cost savings range from close to zero to 18 % with a mean value of 8.5 %. The limited potential for efficiency gains from BCA can be traced back to the fact that import tariffs applied to the industry-average of embodied carbon do not incentivize polluters in unregulated countries to adopt less emission-intensive production techniques (not to mention the consumption side abroad).⁹

⁸ A more precise metric for efficiency (welfare) losses would be the so-called Hicksian equivalent variation (HEV) in income denoting the amount of money which is necessary to add to or deduct from the benchmark income of consumer so that they enjoy a utility level equal to the one in the counterfactual policy scenario (on the basis of ex-ante relative prices). Provided at the global level, efficiency losses are then reported as changes in money-metric utility from a utilitarian welfare perspective, i.e., being agnostic on cost distribution. All model simulations reported adjustment cost also in terms of HEV but we decided to stick to GDP as a more common, policy-relevant cost metric. Note that in our central case simulations, the economic impacts reported in terms of HEV are very close to those reported in terms of GDP.

⁹ Exporters in unregulated countries can to some extent also re-route their products from countries that levy carbon tariffs to unregulated markets.

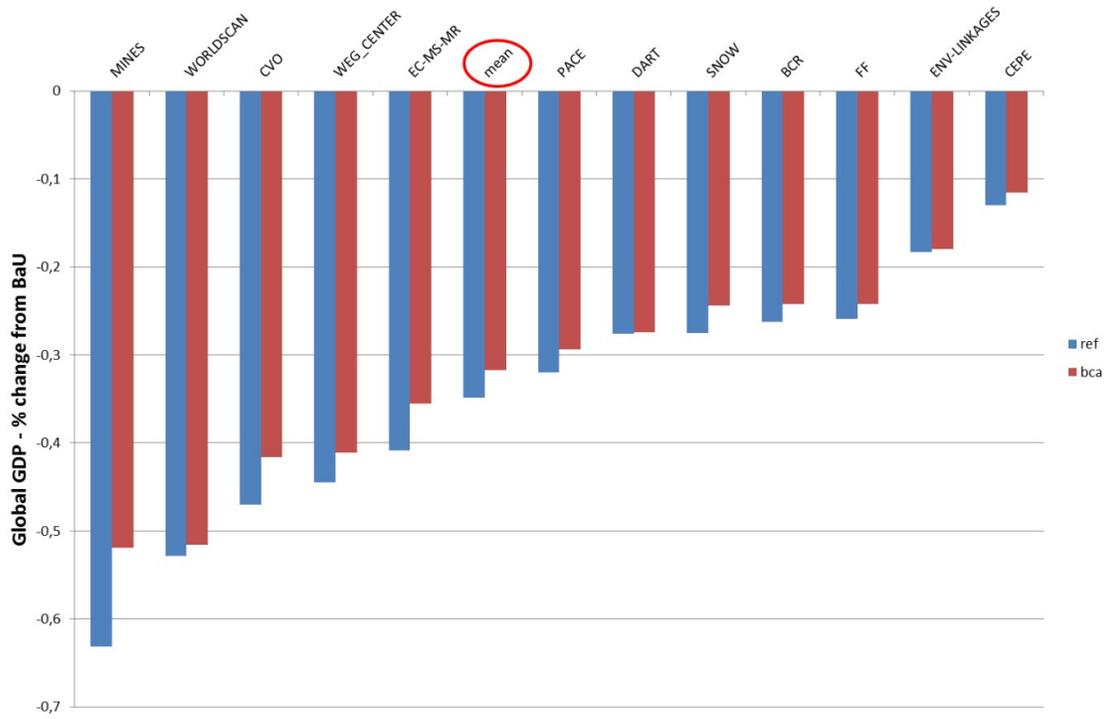


Fig. 5 Global GDP impacts (% change from BaU)

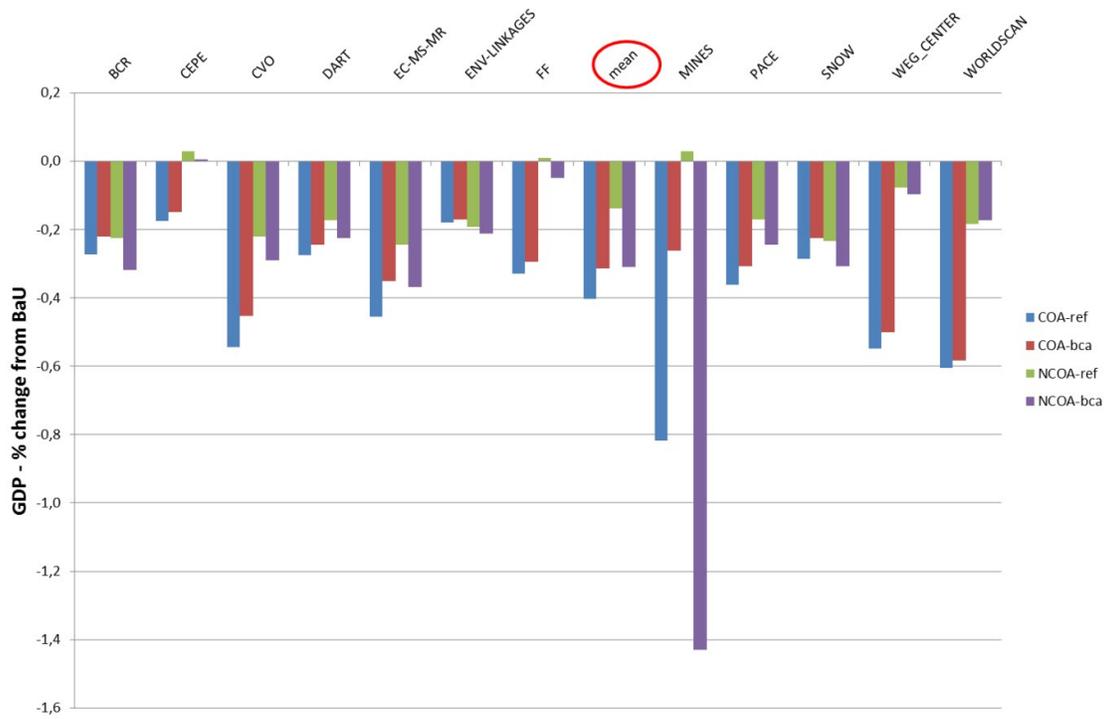


Fig. 6 Burden shifting – GDP impacts for coalition and non-coalition (in % change from bau)

Figure 6 gives insights into potential distributional pitfalls of BCA. Starting from the reference scenario with uniform emission pricing only, we see that unilateral climate policy on average imposes a substantial burden to non-abating countries. The reasoning behind is that non-abating countries suffer from a deterioration of their terms of trade, i.e., the ratio of export prices to import prices. The terms-of-trade losses for the non-abating countries get more pronounced under BCA while abating countries inversely enjoy terms-of-trade gains. Obviously, industrialized countries which are net importers of embodied carbon from the developing world can enact carbon-motivated EITE tariffs to exert market power and change the terms of trade to their favor. The re-distributive impacts of BCA are drastic: While the burden sharing ratio measured in percentage GDP loss for the coalition over the percentage GDP loss for the non-coalition amounts to $3/2$ in the reference scenario, it roughly inverts to $2/3$ for the case of BCA. The model-specific results show substantial variation on the extent of the burden shifting impact of BCA but qualitatively all models are in line.

Deviating from the mean result in qualitative terms, a few models indicate that non-abating regions on average could benefit from the reference scenario with uniform unilateral emission pricing only. This finding echoes conventional wisdom on shifts in comparative advantage (particularly in EITE industries) due to unilateral regulation – at the macroeconomic level, however, most models suggest that non-abating countries in the end will suffer from reduced economic activity in abating countries and terms-of-trade changes.

Fig. 7 provides more detailed insights into region-specific adjustment cost triggered by unilateral action. For the sake of transparency, we restrict our exposition of results to the mean value across models. It is well known in the CGE literature that domestic policies impact on international prices (the terms of trade) which can significantly alter the economic implications of the primary domestic policy (Böhringer and Rutherford 2002). As with leakage, it is useful to distinguish spillovers from fossil fuel markets on the one hand and from non-energy markets on the other hand. Regarding spillovers on fossil fuel markets, cutbacks in international fuel demand of large open economies depress international fuel prices which in turn reduces the energy bill of fuel importers and revenues for fuel exporters. As to spillovers on non-energy markets, abating countries may be able to pass on part of additional production cost to other countries due to product heterogeneity of traded goods.

In our reference scenario, fuel exporting regions – here: Russia and other energy exporting countries (EEX) – are most adversely affected even if they abstain from domestic emission regulation themselves; the primary reason is the decline in fossil fuel prices. On the other hand, countries which are net importers of fossil fuels and do not commit themselves to stringent emission constraints can benefit from unilateral climate policy initiatives (here: India). Terms-of-trade effect on EITE markets are most evident for the case of BCA where all non-abating countries subjected to import tariffs are worse off than without BCA while all the abating countries do better.

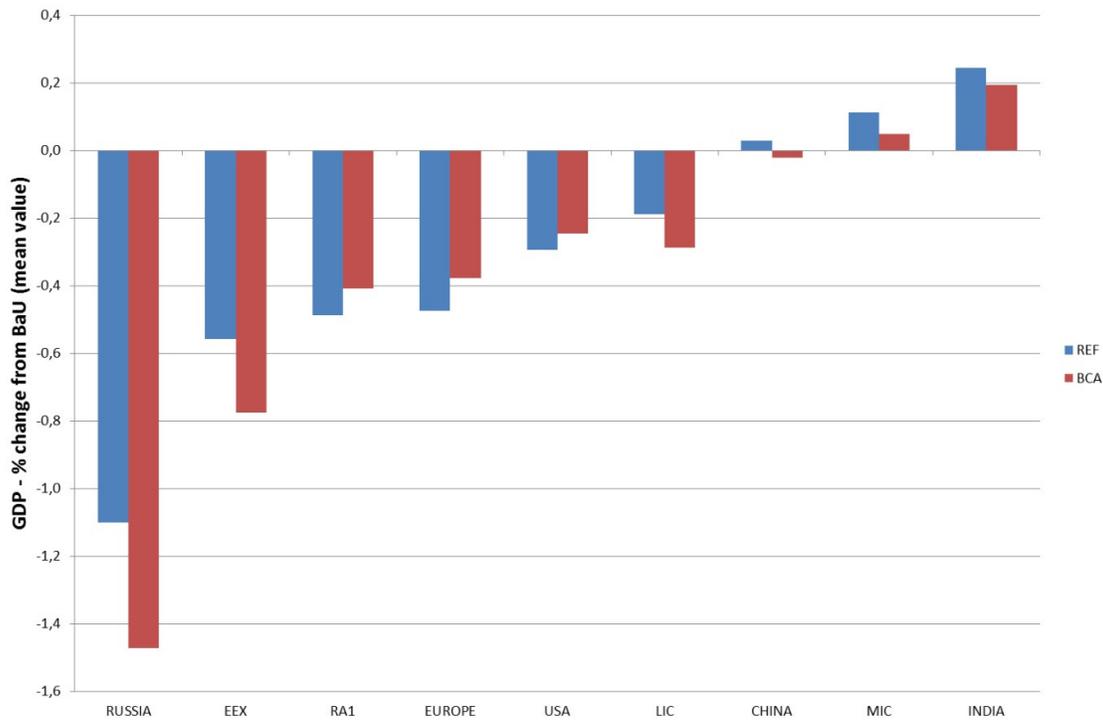


Fig. 7 GDP impacts at single-country level (% change from *baU*)
 RA1 – rest of Annex I; EEX – energy exporting countries excl. Mexico; LIC/MIC – low/middle income countries

3.3. Sensitivity analysis

The previous section discussed our central case simulation results which reflect a specific set of assumptions on unilateral climate policy settings: industrialized countries (including the USA but without Russia) go ahead with stringent coordinated emission regulation and consider the imposition of BCA as a means to deter leakage and preserve competitiveness of EITE industries; BCA includes EITE tariffs on embodied carbon (covering fuel-based direct emissions plus indirect emissions from electricity inputs) joint with rebates of carbon payments to EITE exports; revenues from import tariffs accrue to the importing (abating) country.

To test the robustness of our common findings, we perform sensitivity analysis with respect to important uncertainties in the design of unilateral climate policies: (i) the use of revenues from import tariffs, (ii) the omission of export rebates, (iii) the size of the abatement coalition, (iv) the target year to which emission reduction pledges apply (i.e. the effective reduction requirements), and (v) the supply responses of fossil fuel producers. In the result exposition below, we focus on the mean value across models' estimates.

Figure 8 shows how the incidence of BCA changes as import tariffs are not retained by importing countries but handed back to the exporting regions.¹⁰ This setting would be equivalent to voluntary export restraints on behalf of exporting regions without emission regulation.

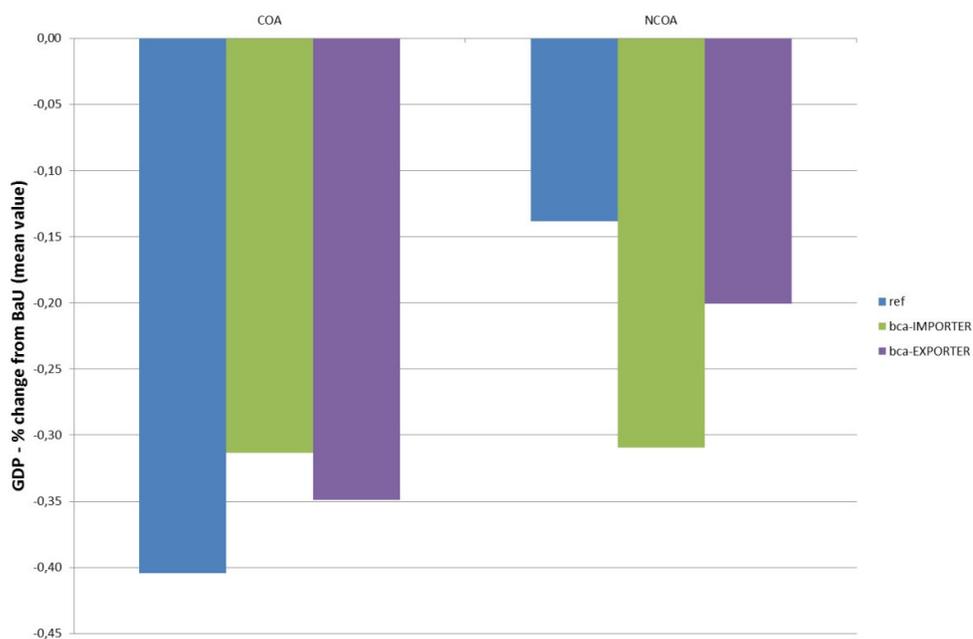


Fig. 8. Global economic impacts (in % GDP change from *baU*) for alternative uses of tariff revenues
 IMPORTER: abating countries (COA) get tariff revenues; EXPORTER: non-abating countries (NCOA) get revenues

As tariff revenues are retained by exporters, the re-distributional effects of BCA vis-à-vis the reference scenario can be markedly reduced – however, the alternative use of revenues cannot fully offset the adverse terms-of-trade effects induced by BCA for the average developing country outside the abatement coalition.

Given the unclear legal status of export rebates, many policy proposals on BCA focus on import tariffs only. We find that border tariffs only have very similar efficiency and equity impacts as full BCA. The main reason is that the abatement coalitions under consideration are larger net importers of embodied carbon such that export rebates play a secondary role. The global efficiency gains of BCA are slightly lower since leakage through the competitiveness channel is higher without rebates to EITE exports. On the other hand, the sole imposition of tariffs slightly enforces the distributional pitfalls of BCA since additional rebates lower EITE export prices and thus ameliorate the adverse terms-of-trade effects for EITE importing regions outside the coalition.

Table 4 summarizes how leakage in the reference scenario and global cost savings through BCA change as a function of the regional coverage of the abatement coalition. We consider three alternative sizes of the abatement coalition: EUR (EU plus EFTA), then our default coalition size A1xR (i.e.,

¹⁰ While direct money transfers may appear as unrealistic, there are at least proposals for the use of these revenues to subsidize clean technology transfer or to feed into (inter-)national funds for climate change mitigation and/or adaptation.

Annex 1 regions with USA but without Russia), and finally A1xR_CHN adds China. As the coalition size increases, leakage becomes less of a problem. The mean leakage rate drops from 23.9 % in the case of EUR to 11.8 % for A1xR, and to 6.7 % for the largest coalition size A1xR_CHN. In relative terms, the cost savings through BCA drop markedly from 16.5 % to 9 % and 2 %, respectively. It should be kept in mind though that the cost base to which the percentage numbers apply increase with the coalition size.

Table 4. Leakage in *ref* and *bca* cost savings as a function of the coalition size

Coalition size	EUR	A1xR	A1xR_CHN
Leakage in scenario <i>ref</i> (%)	23.9	11.8	6.7
Global cost savings in <i>bca</i> (% from <i>ref</i>)	16.5	9.0	4.5

For the central case simulations, the target year of compliance to unilateral emission reduction pledges is set to the base year of the models' parameterization (here: 2004 as provided by GTAP7.1). The upside of this choice is that our economic impact analysis applies to empirical data which is common across all models. The downside is a certain lack of policy appeal since actual policy pledges of industrialized countries (as communicated in the Copenhagen Accords) mostly apply to the target year 2020 or even later. Impact analysis for a future target year, however, requires assumptions how the global and regional economies will evolve which will suffer from huge uncertainties not only at the macroeconomic level but in particular with respect to structural change (e.g., the role of EITE industries in a decade from now). For the sensitivity analysis on the target year 2020, model teams were free to pick their preferred business-as-usual. This degree of freedom implies larger differences on the business-as-usual in 2020 across models owing to alternative exogenous assumptions and alternative baseline calibration techniques for important trends such as the evolution of energy efficiency. At the aggregate level, the commonly shared assumption is that global economic growth goes along with a substantial increase in global carbon emissions. If this trend also applies to the countries of the abatement coalition, emission pledges that are stated with respect to 2004 emissions translate into higher effective targets when expressed as percentage reduction requirement with respect to the business-as-usual emission level in the target year 2020.¹¹

Table 5 reports the implications of the change in the base year from 2004 to 2020 for the A1xR_CHN coalition, that is China plus all industrialized A1 countries (with the USA but without Russia). The 20

¹¹ In this vein, the choice of a future target year is similar to the choice of a more stringent emission reduction keeping the target year at the base year – however, there is an overlay of changes in the structural characteristics of the economy since a more realistic forward-projection does not follow a steady-state growth path.

% reduction pledge with respect to 2004 implies a leakage-adjusted emission cut of 21.3 % for the A1xR_CHN abatement coalition in 2004 which goes up drastically to an emission cut of 41.2 % in 2020. The increase in the effective emission reduction target is mirrored in the sharp increase of CO₂ prices – as we move further out on the marginal abatement cost curves, cheaper abatement options are exhausted and the economy must revert to increasingly expensive adjustments in production and consumption. Likewise, the global economic adjustment cost rise substantially and the leakage rate for the reference climate policy without BCA goes up. On the other hand, our sensitivity analysis indicates that BCA only achieves slightly more cost savings than for the target year 2004. The reasoning behind are the imposed structural changes along the *bau* where EITE trade becomes less important as well as energy efficiency improvements in non-abating regions.

Table 5. Implications of alternative target years for compliance (coalition: A1xR_CHN)

Base year	2004	2020
CO ₂ reduction in coalition COA (% from <i>bau</i>)	-21.3	-41.2
Global CO ₂ reduction (% from <i>bau</i>)	-13.1	-23.1
CO ₂ price in <i>ref</i> scenario (USD per ton of CO ₂)	26.2	104.9
Leakage in <i>ref</i> scenario (%)	6.7	10.3
Global consumption in <i>ref</i> scenario (% from <i>bau</i>)	-0.3	-1.2
Global cost savings through <i>bca</i> (% from <i>ref</i>)	4.5	6.5

At the single country level, the combination of changes in the target year and coverage of the abatement coalition can have dramatic implications. Figure 9 provides an illustration for the case of China. As China enters the abatement coalition in 2004 it faces substantial economic adjustment cost but the latter go up dramatically if China’s 2004 reduction pledge is applied to the target year 2020. The reason is the sharp projected increase of business-as-usual emissions in China.

To investigate the role of fossil fuel market adjustments, the sensitivity analysis comprises additional simulations where fossil fuel producers ration their supply to keep fossil fuel prices at the *bau* level. Table 6 reveals that fossil fuel price changes are a central driver for leakage in our central case simulations. The leakage rate for the reference scenario without BCA drops from 11.8 % to 2.5 % as fuel producers counteract the depression of fuel prices with supply-side rationing (scenario label *ref_ffp*). The imposition of BCA in the latter case (scenario label *bca_ffp*) can even lead to negative leakage. CO₂ prices in the abatement coalition are lower with fuel rationing because leakage rates and

thus the domestic emission requirement to meet the exogenous global emission constraint are smaller. The implications for global cost savings through BCA and the re-distributional impacts between average abating and non-abating regions remain robust. More specifically, fossil fuel price stabilization slightly reduces the cost of non-abating countries at the expense of abating countries since major fuel exporters are part of the non-abatement coalition.

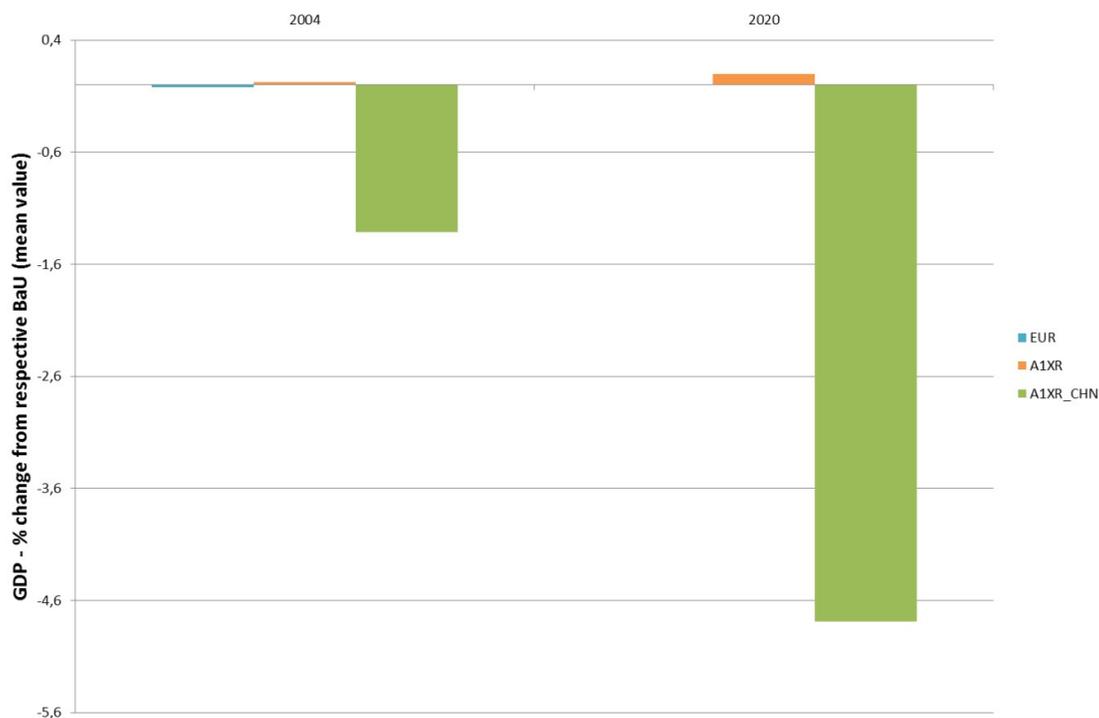


Fig. 9. Cost implications for China for alternative coalition sizes and target years

Table 6. Implications of fuel producers keeping fuel prices constant

Policy	<i>ref</i>	<i>ref_ffp</i>	<i>bca</i>	<i>bca_ffp</i>
Leakage (%)	11.8	2.5	7.6	-3.4
CO ₂ price (USD per ton of CO ₂)	41.7	33.4	39.4	30.6
Global GDP (% from <i>bau</i>)	-0.41	-0.41	-0.38	-0.38
GDP of coalition COA (% from <i>bau</i>)	-0.38	-0.38	-0.25	-0.29
GDP of non-coalition NCOA (% from <i>bau</i>)	-0.53	-0.50	-0.87	-0.77
Cost savings (% from <i>ref</i>)			9.0	5.9

3.4. Brief summary

The interim conclusions of the model cross-comparison are as follows. BCA on EITE goods are effective instruments to reduce leakage and attenuate adverse effects on EITE industries in unilaterally regulated countries. From a global cost-effectiveness perspective, BCA reduce the economic adjustment cost to achieve global emission reduction through unilateral climate policy. However, the cost savings compared to the reference scenario with uniform unilateral emission pricing only are rather limited – the reasoning behind is that import tariffs levied at the industry-average of embodied carbon for EITE firms do not provide direct abatement incentives for foreign producers. The main effect of BCA is redistributive. Domestic climate policies without BCA undertaken by industrialized countries already imply on average a substantial burden to unregulated developing countries due to adverse terms-of-trade effects. The latter are markedly enhanced with the imposition of BCA if revenues are retained by importing regions. While for the reference climate policy without BCA some non-abating countries may actually benefit (predominantly large importers of fossil fuels), the burden shifting effect of BCA from industrialized to developing countries applies uniformly.

4. Specific findings

Beyond the submission of results to the harmonized scenarios of the cross-model comparison each modeling team elaborated further on BCA with a specific focal point. The topics (see Table 1) range from data issues via alternative model hypotheses on economic responses to different climate policy architectures. In the following, we briefly summarize the key findings of the specific contributions and refer for more details to the respective articles in this Special Issue.

The first two papers address the question how aggregation of detailed and heterogeneous production data to composite sector characterization might bias the impact assessment of climate policy regulation at the economy-wide and industry-specific level.

The paper “Estimating carbon leakage and the efficiency of border adjustments in general equilibrium - does sectoral aggregation matter?” by Caron (2012) starts from the observation that CGE models to assess the economic impacts of climate policies are often characterized by coarse sector aggregation reflecting data limitations of global datasets such as GTAP. The question arises if sectoral aggregation can lead to a bias in the economic impact assessment of climate policies at the economy-wide and sectoral level. To answer the question, the author triples the number of industrial sectors in the GTAP dataset exploiting detailed industry-specific data on energy use and trade provided by the Energy Information Administration’s Manufacturing Energy Consumption Survey (MECS) and the Bureau of Economic Analysis (BEA). This leads to larger heterogeneity in energy and emission intensities than GTAP (which can increase demand intensities and reduce abatement costs) as well as larger covariance between energy and trade intensities (which can increase leakage). The author then uses

various levels of sectoral (dis-)aggregation to assess the aggregation bias. He finds that model results based on aggregated datasets overestimate industrial output losses and underestimate the increase in CO₂ embodied in EITE imports (as a measure of leakage through the competitiveness channel). BCA effectiveness in leakage reduction also tends to be underestimated. However, key macroeconomic indicators such as emission prices and economic adjustment cost to emission constraints are almost unaffected by the level of industrial aggregation. Sectoral disaggregation thus is in particular desirable when it comes to industry-specific impact analysis such as the competitiveness implications for EITE sectors.

In the same vein, the paper “The value-added of sectoral disaggregation: implication on competitive consequences of climate change policies” by Alexeeva-Talebi, Böhringer, Löschel and Voigt (2012) investigates the importance of more detailed information for EITE industries than typically provided in global economic databases. The paper first lays out how more disaggregate data provided by the EXIOPOL dataset can be used in a systematic manner to split down composite industrial sectors in the GTAP database. The authors then discuss important dimensions of sectoral heterogeneity which includes base-year production cost shares, the ease of price-responsive input substitution in production, and trade exposure. Sensitivity analysis along these dimensions involves alternative parameterization of disaggregate industrial sectors with respect to technology characterization (captured through energy cost shares, CES nesting structures and substitution elasticities) and substitution possibilities between traded goods (reflected by Armington trade elasticities). The results show that competitiveness effects for EITE industries – in magnitude and sign – are particularly sensitive to the choice of Armington elasticities. Echoing the findings by Caron (2012), the paper points out that the effects of disaggregation for macroeconomic indicators is not as pronounced as for sectoral indicators. The authors conclude that the level of sectoral aggregation provided by the widely-used GTAP database is appropriate for economic impact analysis of climate policy unless the primary interest is into specific sectoral implications.

The next set of three papers investigate how different CO₂ tariff designs, the inclusion of process-based CO₂ emissions and additional pricing of non-CO₂ greenhouse gas emissions affect the efficiency outcomes and distributional effects of unilateral climate policies.

The paper “Alternative designs for tariffs on embodied carbon: a global cost-effectiveness analysis” by Böhringer, Bye, Faehn and Rosendahl (2012) quantifies how alternative tariff designs for embodied carbon in traded goods change global cost-effectiveness of unilateral climate policy. The alternative tariff designs combine different choices for embodied carbon coverage, sector coverage and tariff rate differentiation spanning a large range of policy-relevant implementation options. The quantitative CGE results largely confirm basic economic theory that more inclusive and source-based tariff systems yield higher efficiency gains. However, the more efficient designs lose attractiveness when judged from administrative, legal, and political perspectives. For instance, tariff designs that are more

likely to comply with international law would have a relatively narrow coverage and therefore yield very little in terms of cost-effectiveness. This reflects the more general problem of finding systems that are both feasible and well-targeted in a real global economy. The cost differences between alternative BCA regimes presented in the study can be interpreted as the maximum acceptable cost (administrative, legal, and political) of moving to less feasible regimes for improving overall cost-effectiveness.

The paper “Border tax adjustments in the climate policy context: CO₂ versus broad-based GHG emission” by Gosh, Luo, Siddiqui and Zhou (2012) investigates how “what-flexibility” in greenhouse gas (GHG) abatement affects efficiency and incidence of unilateral climate policies. The abatement coalition can apply uniform emission pricing to CO₂ emissions only or to all greenhouse gases; in addition, the domestic climate policy might be complemented with border tariffs that apply either to embodied CO₂ emissions only or to embodied emissions of all greenhouse gases. The simulation results echo previous findings of the CGE literature on the efficiency gains of “what-flexibility”: Broad-based GHG policies lower economic adjustment cost of climate protection. From a distributional perspective, broad-based GHG policies are also more appealing since burden shifting from industrialized to developing countries is ameliorated – efficiency serves as a maid to relax “equity” tensions. Compared to the changes that emerge from expanding CO₂ pricing to comprehensive greenhouse gas pricing the implications of BCA are of secondary order. The general assessment of BCA if applied to all greenhouse gases coincides with the message from the model cross-comparison on CO₂-only policies: BCA has (limited) potential for global cost savings but faces the pitfall of substantial re-distributive impacts at the expense of the (non-abating) developing world. The differential impacts of BCA for alternative degrees of “what-flexibility” and sectoral coverage are most relevant at the single-country level as illustrated for the case of Brazil: Given that the bulk part of GHG emissions in Brazil stem from non-CO₂ sources with agriculture as the biggest emitter, Brazil will be most adversely impacted under a unilateral GHG policy of industrialized regions where tariffs on embodied greenhouse gas emissions also apply to agricultural products.

Bednar-Friedl, Schinko and Steining (2012) examine „The relevance of process emissions for carbon leakage: A comparison of unilateral climate policy options with and without border carbon adjustment”. The motivation to include process-based CO₂ emissions on top of combustion-based CO₂ emissions into the analysis of unilateral climate policy designs is threefold. First, process-based emissions account for roughly 10% of all CO₂ emissions emerging from the production side of the economy. Second, technological options for the abatement of process-based emissions are limited: Reduction of process emissions typically requires downscaling of output (or costly technology shifts) while combustion-based emissions can be reduced also by input substitution through capital (energy efficiency) or lower-carbon fuels (fuel switching). Third, process-based emissions are in particular relevant for EITE industries that are central to leakage and competitiveness concerns. The authors start their analysis with data work. The GTAP database which reports only combustion-based CO₂

emissions is complemented with CO₂ emissions from industrial processes in three important EITE sectors: non-metallic minerals, iron and steel, and non-ferrous metals. The authors then assess how the impacts of unilateral emission abatement on behalf of the European Union (EU) change as process-based CO₂ emissions are incorporated. They find that inclusion of process emissions results in substantially higher leakage rates to non-EU countries. The reasoning behind is that (i) abatement of process emissions is relatively expensive, (ii) sectors which have lots of process emissions are generally also quite trade-exposed, and (iii) these sectors stand out for higher emission intensities in non-EU regions (compared to their EU competitors). BCA including process emissions is much more effective in leakage reduction than solely combustion-based designs since they target more accurately and comprehensively the driving forces for leakage.

Two papers in this Special Issue are dedicated to the implications of alternative model assumptions regarding fossil fuel supply responses and economic mechanisms that drive international trade.

The paper “Fossil fuel supply, leakage and the effectiveness of border measures in climate policy” by Boeters and Bollen (2012) discusses the critical role of fossil fuel supply elasticities for leakage through the fossil fuel price channel. As well-known, lower elasticities imply a stronger fall in fuel prices following fuel demand reductions in emission abating countries – lower fuel prices, in turn, lead to higher fuel demands in non-abating countries and thus higher leakage through the fossil fuel price channel. Obviously, the relative importance of the fossil fuel price channel vis-à-vis the competitiveness channel for EITE goods hinges on the values for fossil fuel supply elasticities. And so does the performance of BCA which is predominantly directed to leakage reduction through the competitiveness channel. The authors point out that in standard CGE models fossil fuel supply is derived from a constant-elasticity-of-substitution (CES) production function, in which a natural resource is treated as a fixed factor (resulting into decreasing-returns-to-scale production with an upward sloping supply function). While the CES function can be calibrated locally at the benchmark point to reflect an exogenous fuel supply estimate, the effective supply elasticity decreases endogenously in the emission abatement counterfactual which drives up leakage through the fossil-fuel-price channel. The authors then introduce an alternative functional specification for fossil fuel production which keeps the fuel supply elasticity (globally) constant thereby strengthening the relative importance of the competitiveness channel for overall leakage. While BCA directed to EITE products is more effective for the constant-elasticity-of-fuel-supply specification, the differences to the standard CES specification are rather negligible for the unilateral climate policy scenarios investigated.

Balistreri and Rutherford (2012) focus on the role of alternative trade specifications in their paper entitled “Subglobal Carbon Policy and the Competitive Selection of Heterogeneous Firms”. The majority of CGE models used for climate policy analysis explains the pattern of international trade through relative cost differences align with perfect competition and regionally differentiated goods (building on the Armington assumption of product heterogeneity). Following more recent

developments in international trade theory by Melitz (2003), the authors adopt a different explanation for EITE industries which builds on the competitive selection of heterogeneous firms engaged in monopolistic competition and international trade. The paper then compares the standard Armington-type CGE model with the Melitz-type CGE model to quantify the economic impacts of unilateral climate policies. This permits sensitivity analysis of conclusions regarding carbon leakage, the efficacy of border adjustments and burden shifting under the alternative structural (trade) assumptions. Adoption of the heterogeneous-firms structure for EITE industries leads to larger competitive effects and more pronounced leakage through the competitiveness channel – BCA in this setting is more effective than in the standard Armington-type model. As to distributional impacts, the Melitz-type model indicates more scope for non-abating countries to benefit from emission regulation of trading partners. The reasoning behind is that competitive effects favoring EITE industries in non-regulated regions are more accentuated in the Melitz framework through endogenous productivity and entry dynamics that are absent in the standard Armington formulation of trade.

The remaining five papers in the Special Issue discuss BCA in the context of fiscal policy and alternative measures for improving on the global cost-effectiveness of unilateral climate policy initiatives.

In the paper “Fair, optimal or detrimental? Environmental vs. strategic use of border carbon adjustment” Hübler, Peterson and Weitzel (2012) discuss the potential role of BCA as a strategic instrument of trade policy. At first view, economic theory justifies BCA to improve on the global cost-effectiveness of unilateral uniform emission pricing. BCA which level the playing field in international trade and help to internalize the costs of climate damage into commodity prices therefore could be seen as both “fair” and “globally optimal”. However, BCA on imported goods can be also used as a strategic substitute for optimal tariffs, where “optimal” is defined from the perspective of the tariff imposing country which seeks to exploit terms of trade. A further strategic perspective on border tariffs is that they can be used to pressure other countries to take action for emission reductions. The burden-shifting potential of border tariffs constitutes a strategic stick: Unregulated countries may prefer to adopt emission controls of their own than suffer the effects of the tariffs – such a response could significantly lower the global cost of climate policy. On the other hand, countries subjected to embodied carbon tariffs could decide for countervailing tariffs which may lead to a “detrimental” trade war. The authors start from the premise that import tariffs levied on direct emissions plus indirect emissions from electricity inputs constitutes the “fair” rate. In CGE-based simulation analysis they find that all members of an industrialized countries’ abatement coalition (all Annex 1 regions including USA but without Russia) have an incentive to impose BCA rates above the “fair” level in order to exploit (selfishly) market power in international trade. While the average country outside the abatement coalition will suffer from high carbon tariffs, country-specific incentives fall apart when accounting for more heterogeneity in economic structures: Russia and other energy exporters are losing, but the composite of low-income countries is gaining. From a strategic perspective, BCA are

not able to trigger a grand coalition including major emitters such as China and India – a more inclusive unilateral abatement coalition would demand compensating transfers which might be difficult to implement in real policy.

The paper “Unilateral climate policy design: efficiency and equity implications of alternative instruments to reduce carbon leakage” by Böhringer, Carbone and Rutherford (2012) compares three widely discussed anti-leakage instruments to complement unilateral uniform emission pricing: carbon-motivated border tax adjustments (BCA), industry exemptions from carbon regulation, and output-based allocation of emission allowances to EITE industries. All three instruments in isolation are distortionary but in a second-best setting such as unilateral climate policy they can promote overall cost-effectiveness. Beyond the efficiency ranking of the three instruments the authors investigate their distributional impacts, which is another important criterion for the attractiveness of complementary anti-leakage measures. From a political economy perspective, anti-leakage measures are more likely to be uncontroversial across trading partners if they do not further exacerbate income inequalities. The social view on the latter is formalized in the paper through social welfare metrics that take up increasing degrees of inequality aversion ranging from a utilitarian to a Rawlsian perspective. The authors thereby establish a convenient metric to measure efficiency-equity trade-offs across the three anti-leakage measures. The simulation results indicate that none of the three instruments constitutes a “magic bullet” when both efficiency and equity matters. BCA reduces leakage as well as output losses in EITE industries quite effectively and provides global cost savings but BCA also exacerbates regional inequalities. Industry exemptions are less prone to distributional pitfalls but are much less effective in leakage reduction and the attenuation of adverse competitiveness effects for regulated EITE industries. Exemptions have only very small potential for global cost savings and may even increase the cost of unilateral climate policy if emission reduction targets are high (and the opportunity cost of forgiving cheap abatement in EITE industries becomes substantial). Alike exemptions, output-based allocation of emission allowances to EITE industries are less effective in leakage reduction and attenuation of output losses. They provide modest global cost savings without affecting the cost incidence of unilateral abatement action markedly. The analysis indicate that the poor “equity performance” of BCA could be alleviated should the revenues of border tariffs be retained by non-abating countries subjected to BCA.

The paper “Climate policy and fiscal constraints: Do tax interactions outweigh carbon leakage?” by Fischer and Fox (2012) further elaborates on the cross-comparison of BCA, exemptions and output-based allocation but shifts the focus from equity-efficiency trade-offs to the importance of initial tax distortions. The analysis iterates on fundamental insights from the double-dividend literature of environmental regulation. On the one hand, emission pricing may increase the distortionary impacts of initial tax distortions. On the other hand, revenue recycling through cuts in distortionary taxes can at least lower the overall cost of environmental regulation compared to lump-sum transfers. The paper investigates how revenue-neutral cuts of distortionary labor taxes affect the cost of emission regulation

for abating and non-abating regions compared to lump-sum recycling of regulatory rents. The comparison is then extended to the different options of complementary anti-leakage measures. Based on quantitative evidence from CGE simulations the authors find that the cost savings from using emissions revenues to reduce distortionary labor taxes are substantial and dominate the cost savings from anti-leakage measures (in particular for larger coalition sizes and moderate emission targets, i.e., lower leakage rates). Tax interaction effects enhance the efficiency gains from BCA, while output-based rebates or industry exemptions become less attractive. With respect to international burden sharing, the paper comes up with two climate policy choices that consistently benefit both coalition and non-coalition countries: revenue recycling and border adjustments with the tariff revenues being returned to the exporting countries.

The paper “A look inwards: carbon tariffs versus internal improvements in emissions-trading systems” by Springmann (2012) compares the efficiency gains from increased where-flexibility within the abatement coalition against the cost savings from the imposition of carbon tariffs. The default assumption for our cross-model comparison is that countries within the abatement coalition will reduce internal emissions in a cost-effective manner: A cap-and-trade system across all sectors and regions of the abatement coalition assures equalized marginal abatement cost. While this assumption has some appeal for supporting external BTA tariffs (with non-uniform emission pricing, competitiveness concerns would also call for BCA between abating countries), the reality is much more fragmented: National jurisdictions pursue country-specific emission reduction pledges on their own without cost-effective coordination across borders. One important exception is the EU where EU Member States have implemented a multi-jurisdictional emissions trading system – the so-called EU-ETS – to economize on overall abatement cost; however, even in the EU, emission abatement policies are fragmented since the EU-ETS only covers energy-intensive industries whereas the remaining parts of the economy are subject to discretionary non-coordinated regulation by each Member State. Against this background, the paper compares the economic impacts of better internal coordination against the implications of BCA. The numerical CGE analysis quantifies the economic impacts of increasing the sectoral and regional coverage of emissions trading systems across coalition countries with the impacts emerging from the imposition of BCA. The main finding is that increased internal where-flexibility can yield much higher global efficiency gains than BCA. In addition, non-coalition countries on average benefit from increased internal efficiency of the abatement coalition whereas global efficiency gains from BCA are hampered through the implicit burden shifting to non-abating developing countries.

The paper “Alternative approaches for leveling carbon prices in a world with fragmented carbon markets” by Chateau and Dellink (2012) extends the analysis of “where-flexibility” to include also the possibility of carbon offsets purchased from countries outside an abatement coalition. The fundamental efficiency pitfall of unilateral abatement action is that carbon prices are zero outside the abatement coalition. BCA will – for pragmatic reasons – most likely apply at the industry level and

thus does not provide a direct incentive for producers abroad to reduce emission inputs. The global efficiency gains of BCA from reduced leakage are therefore quite limited. Starting from an initial situation with fragmented carbon markets in industrialized countries, the authors investigate two major policy options for reaping larger cost savings through more cooperation that would help to level carbon prices. Intra-coalition cooperation involves the linkage of domestic emission trading systems across domestic borders. Cooperation beyond the jurisdictions of abating countries could be achieved through carbon offsets which – in the vein of the Clean Development Mechanisms under the Kyoto Protocol – allow emission reduction projects outside the abatement coalition. In this case, credits are purchased by regulated entities in acting countries to meet part of their domestic emission reduction commitments. The CGE simulations clearly indicate that extending carbon markets to include more emission sources: Leveling carbon prices not only avoids larger competitiveness tensions for EITE industries but also provides substantial cost savings while avoiding distributional pitfalls.

5. Conclusions

Given the lack of globally concerted action, individual countries move forward with domestic climate policies taking up responsibility in the battle against climate change. Overall cost-effectiveness of unilateral action to deal with the global emission externalities inherently suffers from the lack of comprehensive where-flexibility: Emissions should be abated where it is cheapest world-wide but unilateral action cannot reach out to sovereign jurisdictions without emission regulation in place. Global cost-effectiveness of unilateral emission abatement is further hampered by emission leakage, i.e., the relocation of emissions to parts of the world economy subject to weaker (no) regulation. There are two main channels for leakage: the fuel price channel where unregulated countries increase fuel demand as international prices get depressed from energy demand reductions of abating regions; and the competitiveness channel through shift in comparative advantage of emission-intensive and trade-exposed (EITE) industries. It is in particular this competitiveness channel that justifies concerns in unilaterally abating regions on excessive (inefficient) structural change against their domestic EITE industries.

In the debate on unilateral climate policy design, border carbon adjustment (BCA) figures prominently as a means to reduce leakage and improve the global cost-effectiveness of achieving global emission reductions through unilateral action. The appeal of BCA is intuitive: Tariffs on embodied carbon of goods imported from unregulated trading partners joint with rebates of emission payments on exports from domestic sources level the playing field in international trade while internalizing the cost of climate damage into prices of goods and services. BCA seems attractive under global efficiency and domestic political economy considerations but its practical implementation deserves careful examination. Legal and administrative barriers may significantly constraint the scope for efficiency gains through BCA. Another very contentious issue from a political perspective is the burden shifting

potential of BCA. Tariffs on embodied carbon could be perceived as a means for back-door trade policy where industrialized countries exploit international market power at the expense of trading partners in the developing world – such burden-shifting through BCA is especially problematic in view of the UNFCCC principle of common but differentiated responsibility and respective capabilities.

This study provides quantitative evidence on the efficiency and distributional impacts of BCA. The robust insights that emerge from our cross-model comparison can be summarized as follows:

- BCA can effectively reduce emission leakage through trade in emission-intensive and trade-exposed industries thereby attenuating adverse impacts for these sectors in unilaterally regulating countries.
- The global cost savings of BCA are limited. The main reason is that BCA – when pragmatically applied on the average emission content of industries – does not incentivize emission abatement in firms abroad.
- BCA can have substantial redistributive effects. Carbon tariffs levied by industrialized countries change the terms of trade against the developing world thereby shifting the burden of emission abatement and exacerbating existing income inequalities.
- The inclusion of rebates in BCA is of secondary importance for the efficiency and distributional effects since industrialized countries are major net importers of embodied carbon.
- The attribution of tariff revenues to exporting countries can significantly reduce the adverse distributional impacts of BCA.

The central insights emerging from the cross-comparison are substantiated and complemented through additional findings by the individual modeling groups:

- Tariff designs that are more likely to comply with international law have a relatively narrow coverage of carbon embodied in trade and therefore yield rather negligible efficiency gains.
- The inclusion of non-CO₂ greenhouse gases in unilateral climate policy does not change the overall assessment of BCA. Under global efficiency considerations the gains from increased what-flexibility are much more important than the cost savings through BCA. At the single country level, however, BCA including other greenhouse gases can have markedly negative impacts on industries and countries where non-CO₂ emissions constitute a larger share of overall greenhouse gas emissions.
- BCA including process-based CO₂ emissions are more effective in leakage reduction compared to purely combustion-based designs since they target more accurately and comprehensively the driving forces for leakage through the competitiveness channel.
- Burden shifting through BCA can provide a strategic stick in international negotiation but the scope for coercive “cooperation” seems limited and must be weighed against the risks of retaliation and detrimental trade wars.

- BCA is only one among various domestic policy measures to reduce leakage and to improve global cost-effectiveness of unilateral action. When compared on efficiency and equity grounds with output-based allocation or industry exemptions, BCA reaps the highest (yet rather limited) cost savings but also stand out for adverse distributional impacts if tariff revenues are not handed back to exporting regions.
- Given the limited efficiency gains and the distributional pitfalls of BCA, unilateral climate policy might in first place seek for improving on the cost-effective design of domestic emission regulation. Leveling carbon prices across sectors and regions of countries that consider or have already implemented unilateral climate action promises larger internal cost savings from increased where-flexibility. Similarly, the recycling of revenues from emission pricing to reduce distortionary initial taxes is likely to dominate the gains from BCA by a wider margin. While the pursuit for more internal efficiency of domestic climate policy designs does by itself not exclude the use of additional BCA to increase “external” efficiency, political efforts should be primarily dedicated to those options that promise larger cost savings and are relatively uncontroversial in political terms.
- BCA is no substitute for efforts to promote collective action. From a global cost-effectiveness perspective, unilateral abatement suffers most from zero-emission pricing in countries without emission regulation. Even limited carbon offset policies through instruments such as the Clean Development Mechanism can be much more cost-effective than BCA since they (partially) level emission prices and provide direct incentives for emission reduction abroad.

The robustness of our findings is not only tested against structural variations in unilateral climate policy design but also with respect to changes in data aggregation and alternative modeling assumptions on initial tax distortions, fossil fuel supply responses or drivers of international trade.

The ultimate objective of our cross-model comparison is to put decision makers on an informed basis with respect to the benefits and costs of BCA as a complementary measure to domestic climate policy. While our quantitative analysis can strengthen or weaken qualitative arguments, economic trade-offs must be resolved in the end on the basis of societal values.

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