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DISTRIBUTIONAL ASPECTS OF ENERGY AND CLIMATE POLICY

The Global Effects of Subglobal Climate Policies

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The Global Effects of Subglobal Climate Policies*

Christoph Boehringer, Carolyn Fischer, and Knut Einar Rosendahl

Abstract

Individual countries are in the process of legislating responses to the challenges posed by climate change. The prospect of rising carbon prices raises concerns in these nations about the effects on the competitiveness of their own energy-intensive industries and the potential for carbon leakage, particularly leakage to emerging economies that lack comparable regulation. In response, certain developed countries are proposing controversial trade-related measures and allowance allocation designs to complement their climate policies. Missing from much of the debate on trade-related measures is a broader understanding of how climate policies implemented unilaterally (or subglobally) affect all countries in the global trading system. Arguably, the largest impacts are from the targeted carbon pricing itself, which generates macroeconomic effects, terms-of-trade changes, and shifts in global energy demand and prices; it also changes the relative prices of certain energy-intensive goods. This paper studies how climate policies implemented in certain major economies (the European Union and the United States) affect the global distribution of economic and environmental outcomes and how these outcomes may be altered by complementary policies aimed at addressing carbon leakage.

KEYWORDS: cap-and-trade, emissions leakage, border carbon adjustments, output-based allocation, general equilibrium model

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Individual countries, particularly members of the Organisation for Economic Co-operation and Development (OECD), are in the process of legislating responses to the challenges posed by climate change. The prospect of rising carbon prices raises concerns in these nations about the effects on the competitiveness of their own energy-intensive industries and the potential for carbon leakage, which is conventionally defined as the change in foreign emissions as a share of the domestic emissions reductions. Of particular concern is leakage to emerging economies that lack comparable regulation. In response, certain OECD nations are proposing trade-related measures to complement their climate policies. However, these measures are controversial. Some analysts believe they may harm industries in developing countries while minimally mitigating total global carbon emissions. Others have been more acute, stating that these trade policy measures are disguised restrictions to trade, intended primarily to protect the competitiveness of domestic industries in OECD countries rather than the integrity of emissions reductions.

Missing from much of the debate on trade-related measures is a broader understanding of how climate policies implemented unilaterally (or subglobally) affect all countries in the global trading system. Arguably, the largest consequences are from the targeted carbon pricing itself, which generates macroeconomic effects, terms-of-trade changes, and shifts in global energy demand and prices; it also changes the relative prices of certain energy-intensive goods. And in addition to trade-related measures, other climate policy design options can affect the distribution of outcomes around the world. Using a computable general equilibrium (CGE) model of global trade and emissions, we examine how climate policies implemented in two major economies, the European Union and the United States, affect the global distribution of economic and environmental outcomes, and how these outcomes may be altered by complementary policies aimed at addressing carbon leakage.

Background

Competitiveness and emissions leakage issues have been at the fore of climate policy discussions in all the major economies implementing or proposing to implement significant emissions cap-and-trade programs, including the United States, the European Union, Australia, and New Zealand. The European Union has so far used preferential allocation of grandfathered allowances to energy-intensive manufacturing to allay concerns about losing profits to foreign competitors. The U.S., Australian, and New Zealand proposals employ another form of free allocation—output-based rebating—to offset most of the carbon cost increases to their energy-intensive, trade-exposed sectors.

An important feature of output-based rebating (OBR) is that unlike with ordinary grandfathering, the allocations are updated based on recent measures of economic activity, namely production. Additional production then garners additional allowances, the value of which functions as a subsidy to production. The approach is similar to using tradable performance standards, in that above-average (or above-standard) emitters face a net liability, while below-average emitters get a net subsidy. Although grandfathered allowances are an unconditional transfer that does not affect operating costs, OBR lowers marginal costs, which are stronger determinants of competitiveness than fixed costs, at least in the short run. The U.S. 2009 American Clean Energy and Security Act (H.R. 2454, or ACESA) proposes that the per unit allocation for eligible sectors be 100 percent of average emissions (both direct and indirect), up to a maximum of 15 percent of the total cap. Australia's Carbon Pollution Reduction Scheme would offer the most energy-intensive activities allowances equal to 60 to 90 percent of historical average emissions (direct and indirect), phasing down gradually over time. The European Union plans a similar benchmarking exercise for its next period, but the results will be used to determine grandfathered allowances; still, the fact that allowances will be granted to new entrants and forfeited for significant reductions in capacity means that the allowances are not truly unconditional and in the long run may have properties somewhat similar to OBR.

OBR keeps the playing field level by keeping domestic costs from rising. Thus, while the emissions price ensures that producers still have economic incentives to reduce their emissions intensity, the subsidy discourages them from reducing emissions by decreasing production (Böhringer and Lange 2005; Fischer 2001). This latter effect creates an important tradeoff: without imposing higher prices on "dirty" products that reflect their full carbon footprint, downstream consumers have less incentive to use alternative products or conservation measures to reduce emissions. Although eligible sectors may benefit and leakage may be reduced, those forgone domestic reductions must be made up elsewhere, driving up the emissions price and overall costs to meet the national cap (Fischer and Fox 2007). Therefore, OBR might be justified on efficiency grounds only as a second-best unilateral strategy when leakage rates are substantial (Böhringer et al. 1998a, 1998b).

An alternative policy measure is border carbon adjustments (BCA), which require importers to purchase emissions allowances in proportion to the emissions embodied in the foreign production of the goods. This method levels part of the playing field by bringing the price of imported goods up to the level of those at home, retaining the incentives for consumers to find and innovate low-carbon alternatives. The other side of border adjustment would give rebates to exported goods, based on a benchmark of their emissions intensity; the rebates keep domestic goods competitive on world markets, without offering the subsidy at home. Full border adjustment would combine adjustments for imports and exports, effectively implementing destination-based carbon pricing. However, most policy proposals focus only on import adjustments.

ACESA proposes to transition from OBR to import adjustments for eligible sectors starting in 2020. The legislation exempts imports from countries that are undertaking comparable steps to mitigate greenhouse gas emissions, as well as parties to multilateral climate agreements or sectoral agreements with the United States; least developed nations are also exempt. The idea of border adjustment of carbon pricing has advocates in Europe (e.g., Godard 2007; Grubb and Neuhoff 2006). Although the European Union has no specific plans to use BCA, it is retaining that option for the future, if insufficient international cooperation emerges.

Border adjustments have their own controversies, however. In theory, trade measures against carbon leakage could help support a new multilateral climate agreement (Karp and Zhao 2008). But some analysts voice apprehension that unilateral trade measures could poison future climate negotiations (Houser et al. 2008) or trade relations (ICTSD 2008). For example, the U.S. Trade Representative has vowed to resist any EU attempt to impose climate-linked tariffs on U.S. products. In addition to the political questions, many scholars have asked whether and how border adjustments, particularly unilateral ones, might be compatible with World Trade Organization (WTO) obligations.[1]

Free allocations may have their own potential conflicts with WTO obligations in the Agreement on Subsidies and Countervailing Measures (Charnovitz et al. 2009). Although they can also distort trade, they do not seem to raise the hackles of the trade community in the same way as do import adjustments, perhaps in part because member countries recognize that to implement any serious climate regulation, such allocations will be necessary to gain domestic political acceptance. Thus, these leakage-oriented policies cannot really be evaluated apart from the climate policy which with they are paired. Indeed, in terms of economic impact, domestic carbon cap-and-trade programs are likely to have much stronger effects on trade partners than would countervailing policies.

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[1] See, for example, Charnovitz et al. 2009; Pauwelyn 2007; Bagwati and Mavroidis (2007), de Cendra (2006), and Kommerskollegium 2004; and a summary in Fischer and Fox 2009.

Literature

Several recent studies have analyzed the effects of unilateral or subglobal climate policies in combination with trade measures and allocation schemes. Some of these studies focus just on specific energy-intensive, trade-exposed sectors, like copper, steel, or cement.[2] Although these partial equilibrium studies ignore important global, general equilibrium effects, they provide some useful insights for interpreting results from general equilibrium approaches. Fischer and Fox (2009) compare different border adjustment options with output-based rebating. They find that while all such policies improve domestic competitiveness for a given sector, none necessarily reduce global emissions, since some emissions are being repatriated along with output. The results depend on the relative elasticities of substitution, as well as relative emissions rates between home and foreign goods. They also note important general equilibrium effects of the climate policies themselves, driven by global energy price changes as well as relative price changes for manufacturing: countervailing policies merely affect the latter, but the full extent of emissions leakage is much more sensitive to the former.

Multicountry, multisector computable general equilibrium (CGE) models are typically used to study the global effects of climate policy, and their specifications can have important implications for leakage and policy outcomes. Many of these studies concentrate on the economic effects on the implementing parties, as well as the implications for global emissions. Peterson and Schleich (2007) investigate border carbon adjustment options for Annex B (industrialized) countries, concentrating on the calculation of the carbon content for imports, which affects the stringency of the border adjustment, and on the breadth of their application across sectors. They find that border adjustment increases the welfare losses for unilaterally abating regions, in part by driving up carbon prices and shifting burdens to less intensively traded sectors. Fischer and Fox (2007, 2009) compare designs for domestic rebate (output-based allocation) programs within a unilateral U.S. climate policy. Their model also considers interactions with labor tax distortions, and they show that output-based rebating (designed appropriately) can generate lower leakage and higher welfare than grandfathering and, in some circumstances, even auctioning.

Burniaux and Martins (2000) show that average (economy-wide) leakage is highly sensitive to the parameterization of fossil fuel supply curves. Average leakage rates in various CGE studies range from 10 to 30 percent (Babiker and

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[2] See, for example, Gielen and Moriguchi 2002; Demailly and Quirion 2006, 2008a; Ponssard and Walker 2008; Fischer and Fox 2009.

Rutherford 2005), although some models report leakage rates below 10 percent for a coalition of Annex I countries, those with reduction commitments under the Kyoto Protocol (Burniaux et al. 2009; Mattoo et al. 2009) and other models find rates above 100 percent for oligopolistic market structures with increasing returns to scale (Babiker 2005). For individual sectors, however, calculated leakage rates can be much higher than the average leakage rates (Paltsev 2001; Fischer and Fox 2009; Ho et al. 2008).

Böhringer et al. (1998a) show that leakage rates are also highly sensitive to the specification of international trade in the CGE model, with important implications for the efficiency effects of output-based allocation of emissions allowances. If products of the same variety produced in different regions are traded as homogeneous goods, leakage rates are rather high and a policy of output-based allocation turns out to be pareto-superior to auctioned permits (or likewise uniform emissions taxes). If, however, these traded goods are treated as qualitatively different, leakage rates are rather low and the better unilateral climate policy applies auctioned permits rather than output-based allocation.

Babiker and Rutherford (2005) consider a coalition of Kyoto ratifiers pursuing their emissions targets; the reference scenario, where coalition members implement Kyoto with no border adjustment, is compared with scenarios with such adjustment measures as import tariffs, export rebates, exemption of energy-intensive industries, and voluntary export restraints by noncoalition countries. They find that most coalition members are better off with tariffs rather than rebates for mitigating their own welfare losses. Exemptions are the most costly to the coalition members but the most effective at reducing carbon leakage. Major noncoalition members, like China, India, and Brazil, are found also to benefit from the adjustment policies, with the exception of the import tariff policy.

Mattoo et al. (2009) also look at the effects of border carbon adjustment options implemented by a coalition of industrialized countries. In their analysis, Mattoo et al. find that import taxes confer the largest welfare losses on lower- and middle-income countries, particularly when imposing countries fully adjust for emissions intensities in the country of origin. Mattoo et al. argue that border adjustments based on domestic or best-available technology emissions rates are able to offset most of the competitiveness impacts with less detrimental effects on developing countries. They also downplay the leakage effects but note that these are sensitive to the major parameter assumptions.

The purpose of this paper is to explore more deeply the effects of unilateral climate policies in the United States and the European Union on welfare, competitiveness, and carbon leakage in different parts of the world. We consider climate policies that differ with respect to their treatment of the energy-intensive sectors (EIS) that both are sensitive to climate policies and have significant international trade volumes.

The policies we consider are (i) full auctioning of all allowances, (ii) output-based allocation to EIS, (iii) import tariffs for EIS goods based on their embodied carbon (using direct emissions in export country), (iv) export rebate to EIS sectors, and (v) full border adjustments—that is, a combination of (iii) and (iv).

Model structure and parameterization

To quantify the economic and emissions effects of unilateral carbon abatement strategies, we build on a generic multiregion, multisector CGE model of global trade and energy use established by Böhringer and Rutherford for the economy-wide analysis of climate policy issues (see Böhringer and Rutherford 2010 for a recent application of the static model versions and its detailed algebraic description). A multiregion setting is essential for analyzing the economic consequences of climate policy regimes: in a world that is increasingly integrated through trade, policy interference in larger, open economies not only causes adjustment of domestic production and consumption patterns but also influences international prices via changes in exports and imports. The changes in international prices—that is, the terms-of-trade—imply secondary effects that can significantly alter the effects of the primary domestic policy. In addition to the consistent representation of trade links, a detailed tracking of energy flows as the main source for emissions of carbon dioxide (CO_2) is a prerequisite for the assessment of climate policies.

The static CGE model used for our numerical analysis features a representative agent in each region that receives income from three primary factors: labor, capital, and fossil fuel resources (coal, gas, and crude oil). Labor and capital are intersectorally mobile within a region but immobile between regions. Fossil fuel resources are specific to fossil fuel production sectors in each region. Production of commodities other than primary fossil fuels is captured by three-level constant elasticity of substitution (CES) cost functions describing the price-dependent use of capital, labor, energy, and material in production. At the top level, a CES composite of intermediate material demands trades off with an aggregate of energy, capital, and labor subject to a constant elasticity of substitution. At the second level, a CES function describes the substitution possibilities between intermediate demand for the energy aggregate and a value-added composite of labor and capital. At the third level, capital and labor substitution possibilities within the value-added composite are captured by a CES function, whereas different energy inputs (coal, gas, oil, and electricity) enter the energy composite subject to a constant elasticity of substitution. In the production of fossil fuels, all inputs, except for the sector-specific fossil fuel resource, are aggregated in fixed proportions. This aggregate trades off with the sector-specific fossil fuel resource at a constant elasticity of substitution. The latter is calibrated to be consistent with supply elasticities of 1 for crude oil and natural gas and 4 for coal. These elasticities are in line with other studies (e.g., Aune et al. 2008) and reflect differences in the market structure and production flexibility across the fuels.

Final consumption demand in each region is determined by the representative agent who maximizes utility subject to a budget constraint with fixed investment (i.e., given demand for the savings good) and exogenous government provision of public goods and services. Total income of the representative household consists of net factor income and tax revenues. Consumption demand of the representative agent is given as a CES composite that combines consumption of nonelectric energy and a composite of other consumption goods. Substitution patterns within the nonelectric energy bundle are reflected by means of a CES function; other consumption goods trade off with each other at a unitary elasticity of substitution (i.e., a Cobb-Douglas relationship).

Bilateral trade is specified following the Armington (1969) approach of product heterogeneity—that is, domestic and foreign goods are distinguished by origin.[3] All goods used on the domestic market in intermediate and final demand correspond to a CES composite that combines the domestically produced good and the imported good from other regions differentiated by demand category *g*. That is, the composition of the Armington good differs across sectors and final demand components. Domestic production is split between input to the formation of the Armington good and export to other regions subject to a constant elasticity of transformation. The balance-of-payment constraint, which is warranted through flexible exchange rates, incorporates the base-year trade deficit or surplus for each region.

Figure 1 provides tree diagrams for the nesting structure in production and consumption underlying the actual model specification (CES stands for constant elasticity of substitution, and CET stands for constant elasticity of transformation).

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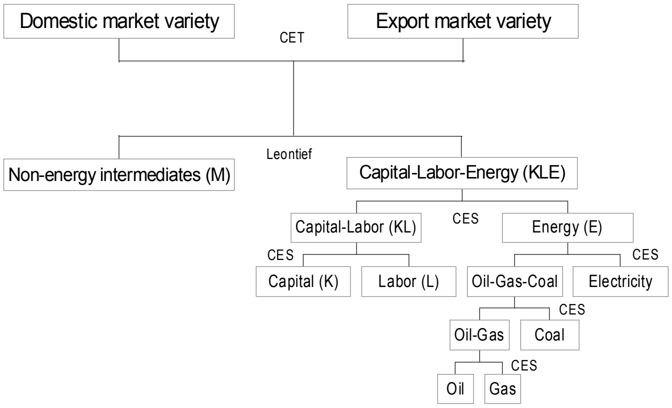
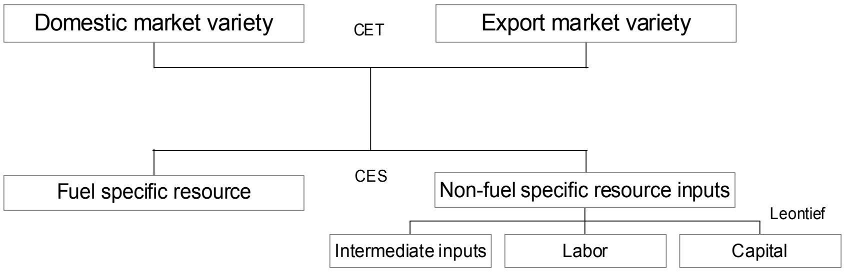
[3] The only exception is crude oil, where we assume product homogeneity.

Figure 1. Nesting structure in production and consumption

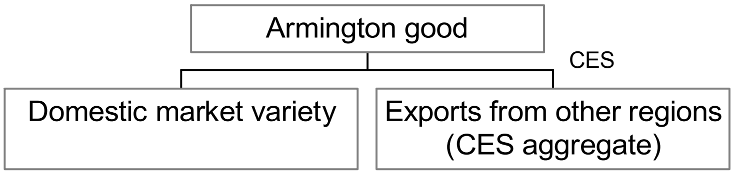
1a. Production (except for fossil fuels)



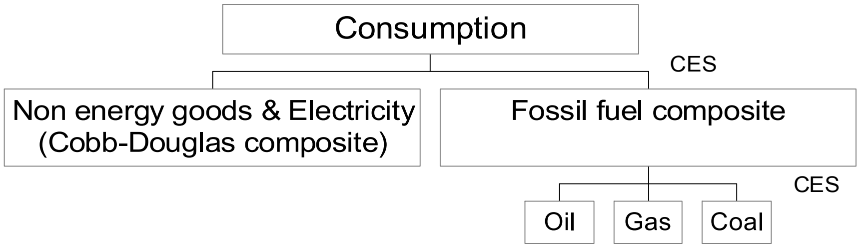
1b. Fossil fuel production



1c. Armington good production



1d. Final consumption



CES = constant elasticity of substitution
CET = constant elasticity of transformation

The model builds on the most recent Global Trade Analysis Project (GTAP) data set with detailed accounts of regional production, regional consumption, and bilateral trade flows as well as energy flows and CO_2 emissions, all for the base year 2004 (Badri and Walmsley 2008). As is customary in applied general equilibrium analysis, base year data together with exogenous elasticities determine the free parameters of the functional forms. Elasticities in international trade are based on empirical estimates reported in the GTAP database.

As to sectoral and regional model resolution, the GTAP database is aggregated toward a composite data set that accounts for the specific requirements of international climate policy analysis. At the sectoral level, the model captures details on sector-specific differences in factor intensities, degrees of factor substitutability, and price elasticities of output demand to trace the structural change in production induced by policy interference. The energy goods identified in the model are coal, crude oil, natural gas, refined oil products, and electricity. This disaggregation is essential for distinguishing energy goods by CO_2 intensity and the degree of substitutability.

The model then incorporates CO_2-intensive (energy-intensive) commodities with significant shares of international trade that are potentially most affected by unilateral climate policies and therefore are considered for border adjustment measures: chemicals (CRP); nonmetallic minerals (NMM), a category that includes cement, glass, and ceramic production; pulp, paper, and print (PPP); iron and steel (I_S); and nonferrous metals (NFM), the category including copper and aluminium. The remaining sectors include transport services and a composite of all other industries and services.

With respect to the regional disaggregation, the model covers the industrialized and developing regions that are major players in international climate negotiations and at the same time intertwined through bilateral trade links: the United States, the European Union, Canada, Japan, Russia, China, India, Brazil, Mexico, and Australia–New Zealand (Aust.NZ). The model also encompasses the Organization of Oil Exporting Countries (OPEC) and aggregate regions for other Asia (Oth.ASIA), other America (Oth.AMER), other Africa (Oth.AFR), other Europe (Oth.EUR), and other former Soviet Union (Oth.FSU).

The calibration is a deterministic procedure and does not allow for a statistical test of the model specification, other than the replication of the initial benchmark. The policy simulations compute counterfactual equilibria to provide information on the policy-induced changes on major economic variables. Recognizing the reliance on exogenous elasticity values and a single base-year observation, as well as the much greater complexity of actual policies, one should not interpret the results as forecasts of outcomes, but rather use them for understanding essential trade-offs, directions of impact, and general rather than precise measures of potential magnitude. Further sensitivity analysis can enhance confidence in policy recommendations.[4] For example, Burniaux and Martins (2000), as well as Babiker and Rutherford (2005), have conducted extensive multidimensional sensitivity analysis in general equilibrium models of carbon leakage, finding that the results are particularly sensitive to assumptions about fossil fuel supply elasticities, but manufactured product differentiation and capital mobility are less influential. In our model, we find that our qualitative conclusions remain robust to a variety of specifications for the fossil fuel supplies, although the magnitudes of the effects do vary.

Policy scenarios

Our reference scenario is one without climate policies, the historical outcome of the base year of the model, 2004. Note that this was before the EU Emission Trading Scheme (ETS) was implemented, and before the Kyoto Protocol entered into force. Thus, climate policies are almost absent internationally, and importantly, no cap exists on emissions in Annex B countries.

The policy scenarios are presented in Table 1. Scenarios 1A–1E assume that the United States unilaterally reduces its domestic CO_2 emissions. Common to all five scenarios is that all sectors of the economy face the same price on CO_2 emissions through an economy-wide cap-and-trade system. This price will, however, differ across the five scenarios.

In Scenario 1A (“AUCTION”), U.S. emissions are reduced by 20 percent compared with the base-year level. Furthermore, all quotas are auctioned off, and no other policies are implemented. As we do not consider revenue recycling, this scenario is equivalent to grandfathered permits, citizen dividends, or the like.

Scenarios 1B–1E all have special treatments for energy-intensive sectors or industries (EIS) that are considered to be significantly trade exposed (the aforementioned sectors of iron and steel; chemical products; nonmetallic mineral products; paper, pulp, and print; and nonferrous metals). To abstract from the need to consider environmental benefits of climate policies, we construct Scenarios 1B–1E to have the same global emissions reduction as in Scenario 1A, which turns out to be 4 percent (see Table 1). Because the special treatment of energy-intensive sectors will tend to reduce carbon leakage (i.e., increase emissions abroad), the emissions reduction in the United States will be slightly lower than 20 percent in Scenarios 1B–1E (cf. Table 2).

Scenario 1B (“OUTPUT”) represents the combination of the economy-wide cap with output-based rebating to the EIS. It assumes that quotas are

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[4] See Böhringer et al. (2003).

allocated free of charge to these industries in proportion to their production level. The allocation rate is adjusted such that the total allocation to energy-intensive industries equals their share of base-year emissions, adjusted for the reduction in total emissions (defined by the cap).

Scenarios 1C–1E assume that the cap-and-trade system is complemented by different border adjustment policies directed toward energy-intensive industries. In Scenario 1C ("REBATE"), export of EIS goods is rebated in proportion to export levels such that the total value of rebates equals the total costs of CO_2 quotas needed to produce these exported goods. In Scenario 1D ("TARIFF"), a tariff is imposed on imports of energy-intensive goods. The tariff is set equal to the embodied carbon in the EIS good[5] times the price of carbon in the domestic cap-and-trade system. The tariff is differentiated across regions such that regions with relatively high emissions in producing an EIS good face a relatively high tariff. Scenario 1E ("BTAX") combines the export rebate and the import tariff—that is, a combination of Scenarios 1C and 1D.

Scenarios 2A–2E are similar to Scenarios 1A–1E except that the European Union instead of the United States reduces domestic CO_2 emissions (by 20 percent in Scenario 2A). Note that the global emissions reduction will be lower in these scenarios than in Scenarios 1A–1E because EU emissions are considerably below U.S. emissions in the reference scenario.[6] Note also that the economy-wide cap differs from the actual EU ETS, which covers only energy and energy-intensive manufacturing sectors.

Scenario 3A assumes that both the United States and the European Union impose a 20 percent reduction in their CO_2 emissions, whereas Scenarios 3B–3E have the same global emissions as Scenario 3A, achieved by ratcheting the U.S. and EU targets proportionately. Obviously, global emissions reductions are bigger than in Scenarios 1A–1E and 2A–2E. We do not have international emissions trading in these scenarios, so carbon prices differ between the United States and the European Union. In the border adjustment cases, we assume that the export rebate is not given for exports from the United States to the European Union (or vice versa), and similarly, import tariffs are not imposed on imports from the European Union and the United States.

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[5] We only consider the direct emissions embodied in the EIS good. For example, indirect emissions from using electricity produced by coal power are not included here. The tariff we consider can of course give incentives to switch from using fossil fuels to using electricity, without necessarily reducing total emissions from producing these goods.

[6] As a consequence, the environmental benefits of Scenarios 2A–2E will be lower than in Scenarios 1A–1E, which should be kept in mind when comparing the effects of U.S. and EU policies.

Table 1 summarizes the scenarios. All scenarios in the first column ("A") assume a 20 percent cut in domestic CO_2 emissions (U.S. and/or EU), and all scenarios in the same row have identical cuts in global CO_2-emissions.

Table 1. Policy scenarios

	A (Auction)	*B (Output)*	*C (Rebate)*	*D (Tariff)*	*E (Btax)*	*Global emissions reduction*
1	U.S.	U.S.	U.S.	U.S.	U.S.	4.0%
2	EU	EU	EU	EU	EU	2.4%
3	U.S. and EU	U.S. and EU	U.S. and EU	U.S. and EU	U.S. and EU	6.6%

Simulation results

We first discuss the economic welfare effects at home and abroad of the primary policies of reducing domestic CO_2 emissions in the United States and/or in the European Union. Economic welfare impacts are reported as Hicksian equivalent variation in income, which denotes the amount necessary to add to (or subtract from) the benchmark income of the representative consumer so that she enjoys a utility level equal to the one in the counterfactual policy scenario on the basis of *ex ante* relative prices. In our analysis we do not attempt to measure the economic benefits of emissions reductions. Because we omit environmental benefits, to avoid confusion, we subsequently use the term *consumption* instead of *economic welfare*. To put it differently, while keeping global emissions reductions constant within each of our three scenario categories, we provide a consistent cost-effectiveness analysis across policy variants A–E. Subsequently, we compare the effects of combining the emissions caps with countervailing policies and discuss the implications for carbon leakage and competitiveness.

Figure 2 presents the consumption effects, by region, of the three auctioned emissions cap scenarios: the United States alone (1A), the European Union alone (2A), and both economies (3A). We first notice that the costs of these targets are substantially higher in the European Union than in the United States. This result may emerge from two important differences. First, the United States has cheaper abatement options than the European Union, with respect to both energy efficiency improvements and fuel switching in the electricity sector. The resulting carbon prices are \$14.70/ton CO_2 for the U.S. unilateral auction policy, compared with \$33.30/ton for the European Union. Both prices rise slightly (to \$15.40 and \$34.10, respectively) when the cap-and-trade programs are jointly implemented, since emissions reductions in either of the two regions will tend to increase emissions in the other region (cf. the discussion of carbon leakage below). Second, the countries have different trade intensities and terms-of-trade effects. For example, we also see that the consumption reductions in the European Union are lower when the United States also cuts its emissions (3A vs. 2A), whereas the United States faces slightly bigger consumption reductions when the European Union also cuts its emissions (3A vs. 1A). Natural gas prices are stimulated by the climate policies, whereas coal and crude oil prices are depressed.[7] The European Union is a net importer of all three fossil fuels, whereas the United States was a net exporter of coal in 2004.

Next, if only the United States or the European Union reduces CO_2 emissions, the effects on total consumption can be quite different for other trade partners. In particular, Russia is made better off by emissions reductions in the European Union because of higher gas export revenues, but it is severely harmed by reductions in the United States because of lower oil export revenues. Brazil and Canada are worse off when the European Union reduces emissions but unaffected or better off when the United States reduces emissions. China, Other Asia, Other America, and Other Africa are also harmed much more by EU policies than by U.S. policies. This is somewhat surprising, given that the *absolute* level of emissions reductions is lowest when only the European Union cuts emissions by 20 percent. One explanation is that climate policy is more costly in the European Union than in the United States, and lower incomes reduce import demand and hence export prices in other regions (remember also that the EU economies are more trade intensive than the U.S. economy).

Indeed, several other regions are worse off than the United States and the European Union when both these two regions reduce their CO_2 emissions by 20 percent. In particular, OPEC experiences a joint loss in consumption of 1.3 percent, mainly because of lower crude oil prices. Other oil exporting regions or countries, like Russia and other former Soviet Union republics, Mexico, and Africa, all see consumption losses even larger than the U.S. consumption losses. On the other hand, countries that import crude oil and coal, like Japan and especially India, benefit from lower international crude and coal prices. Canada actually gains when the United States, its close neighbor, takes on emissions reductions. Canada increases its output and net export of both natural gas and energy-intensive goods, and it suffers a consumption loss only when the European Union alone reduces emissions. Global consumption is actually reduced more in

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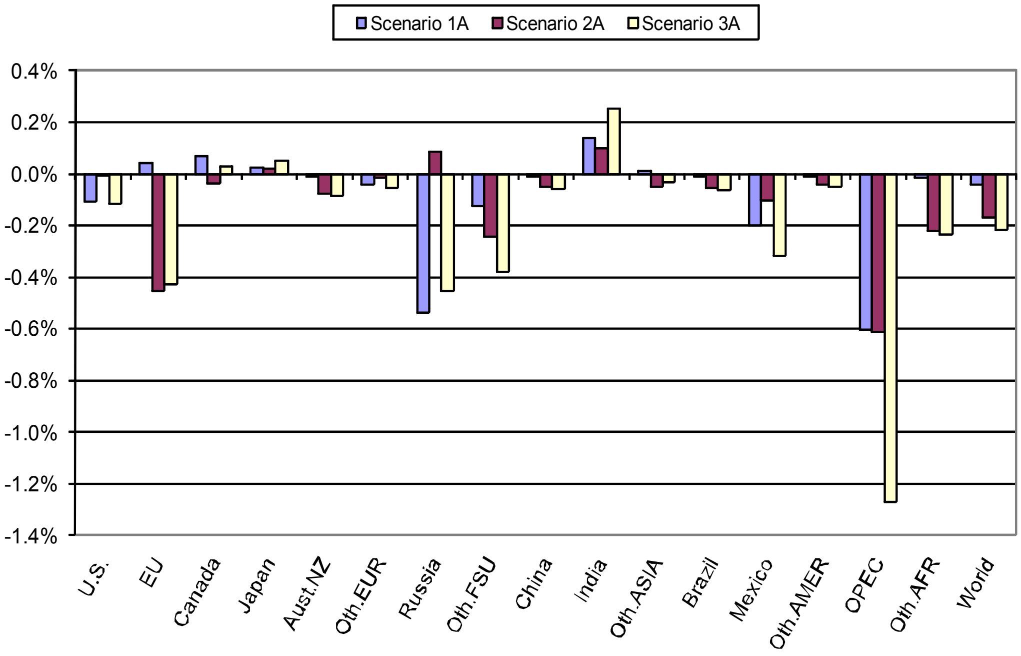
[7] In these three scenarios, U.S. and EU coal prices fall 15–1 percent, crude prices fall 1–2 percent, and natural gas prices increase 6–8 percent.

relative terms than U.S. consumption when both the United States and the European Union cut back their emissions.

Figure 2. Consumption effects of 20% cut in CO_2 emissions by United States, European Union, or both, under auctioning (Scenarios 1A, 2A, and 3A)



Next, we consider the effects of the countervailing policies. Table 2 shows the domestic emissions reductions in the different scenarios. As already indicated, the complementary policies imply less domestic reductions in order to reach the same global emissions reductions. We also notice that the biggest changes are in the European Union. This greater sensitivity is likely driven by the fact that EIS emissions represent a larger share of the cap in the European Union than in the United States. Improved competitiveness of EIS sectors through OUTPUT or BTAX, which affects foreign emissions, then requires fewer domestic emissions reductions to meet the global target (cf. also the discussion of leakage below).

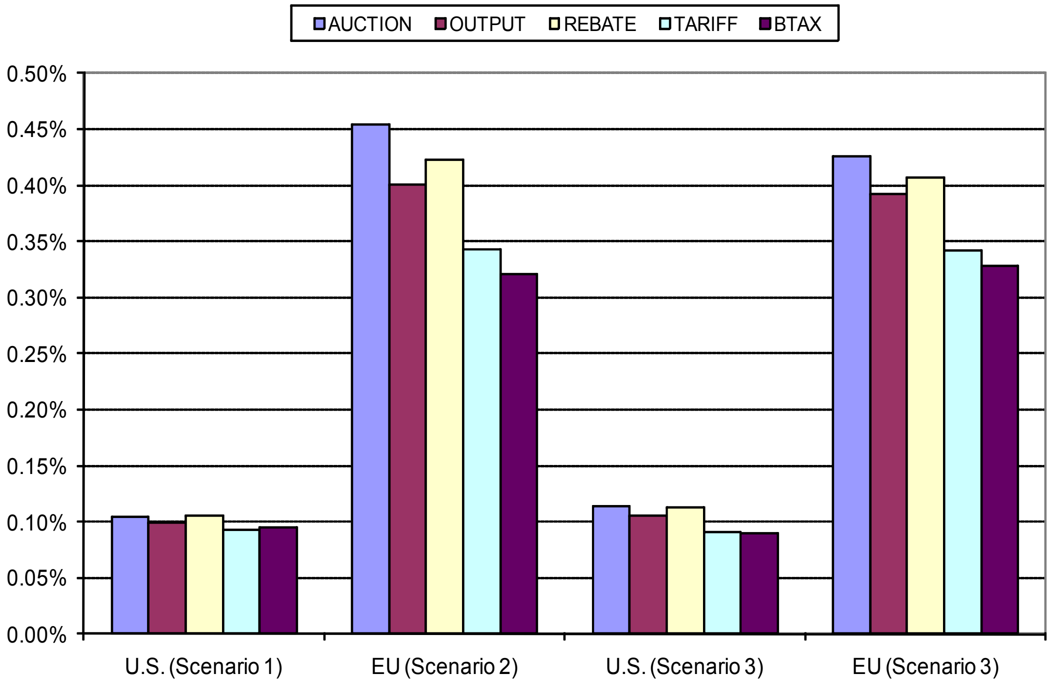
Table 2. Emissions reductions, by policy scenario

	Domestic emissions reductions (percentage)					*Global reduction*
	A (Auction)	*B (Output)*	*C (Rebate)*	*D (Tariff)*	*E (Btax)*	
1 (U.S.)	20.0	19.8	19.9	19.8	19.7	4.0
2 (EU)	20.0	19.3	19.5	18.6	18.2	2.4
3 (U.S. and EU)	20.0	19.7	19.8	19.3	19.1	6.6

Figure 3 shows the costs, in terms of reduced consumption, for the United States and the European Union. When we compare the five policy options, we see that the cost differences are rather small in the United States but somewhat larger in the European Union. The two most expensive policies (from a domestic point of view) in both regions are auction and export rebates. Import tariffs, possibly complemented with export rebates, are the least expensive policy option in both economies. This assumes, however, that import tariffs can be differentiated across regions based on differences in embodied carbon. If the tariffs also accounted for indirect emissions (cf. footnote 5), additional simulations show that the costs would be even lower. Because the environmental benefits are held constant across the five policy options, we may conclude that both the United States and the European Union are better off in terms of welfare with special treatment of energy-intensive industries.

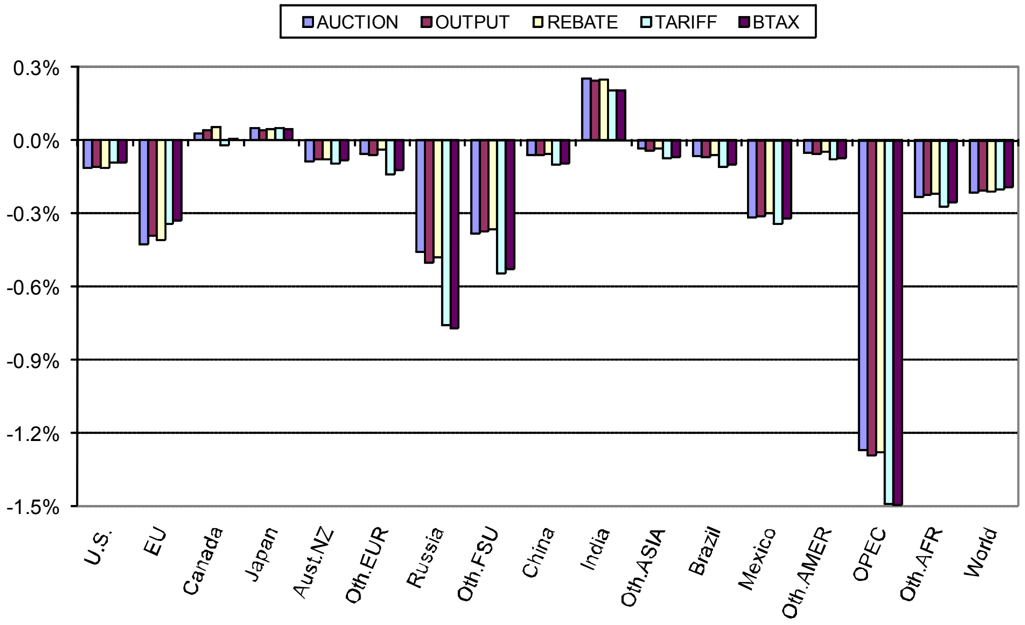
The fact that other policies dominate an auctioned cap reflects to some degree the auctioned cap's increased domestic emissions reductions. However, even if the *domestic* emissions reductions are kept constant, at 20 percent, both output-based allocation and import tariffs reduce the costs slightly. This is due to some beneficial terms-of-trade effects from protecting EIS in these two large economies. Interestingly, the U.S. carbon price is almost insensitive to the adjustment policies, but the EU carbon price *decreases* 4 percent in the OUTPUT scenario and 13 percent with BTAX. Thus, the effect of increased competitiveness for EIS sectors, which would tend to increase the carbon price needed to reach a fixed domestic target, is dominated by the effect of lower domestic emissions reductions.

Figure 3. U.S. and EU costs (reduced consumption) of cut in CO_2 emissions



As shown in Figure 4, the differences among policies are moderate for most regions and small for the world as a whole. However, the consumption losses for crude oil and coal exporters are generally highest when the United States and the European Union also impose import tariffs, in which case the demand for fossil fuels outside these two regions is lower than in the other scenarios, leading to even lower fossil fuel prices (see the discussion of leakage below). Import tariffs also hurt exporters of energy-intensive goods, notably China, India, and Canada. We also observe from the figure that total costs for the world are lower with special treatment of energy-intensive industries, which presumably is due to generally higher emissions intensities for these sectors outside the United States and (especially) the European Union.

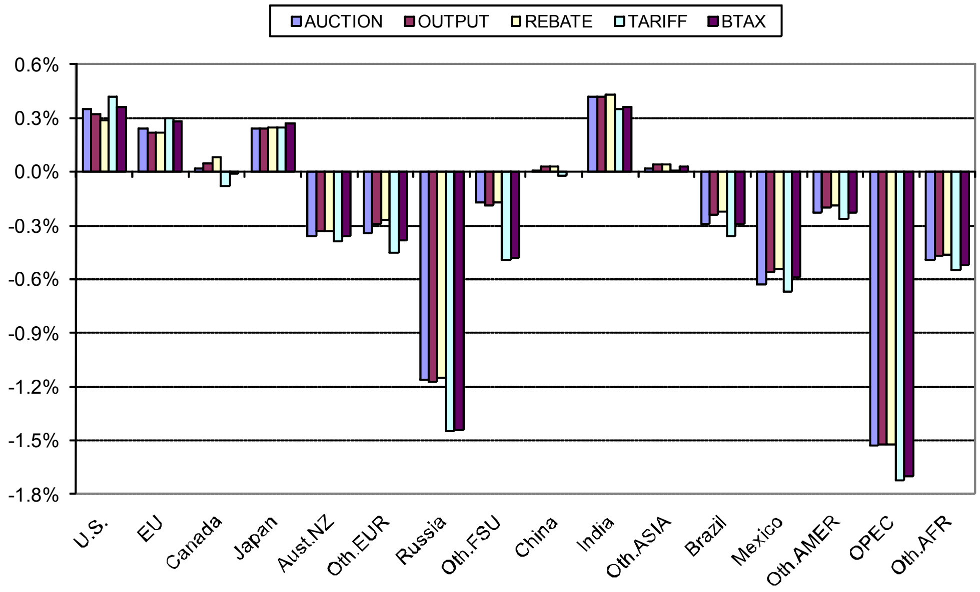
Figure 4. Consumption effects of cut in CO_2 emissions in both United States and European Union (Scenarios 3A–3E)*



* The results for the United States and the European Union are the same as the last 10 bars in Figure 3.

The importance of international price effects of climate policy in the United States and the European Union is readily apparent from Figure 5, which shows the change in the Laspeyres index for the different regions (in Scenarios 3A–3E). The Laspeyres index of the terms of trade measures the ratio of the price index of exports to the price index of imports, in which prices are weighted by the baseline quantities of exports and imports. For the regions without emissions constraints, we notice that their consumption effects, as shown in Figure 4, can to a large degree be traced back to changes in the international prices triggered by the U.S. and EU emissions policies. For the United States and the European Union, the two figures illustrate that beneficial terms-of-trade effects contribute significantly to reducing the overall costs of climate policies in these regions. In particular, the percentage reduction in U.S. consumption is clearly below the percentage increase in the country's Laspeyres index. Not surprisingly, Figure 5 shows that import tariffs give more advantageous terms-of-trade effects than other policies for both the United States and the European Union.

Figure 5. Terms-of-trade effects (Laspeyres index) of cut in both U.S. and EU CO_2 emissions (Scenarios 3A–3E)

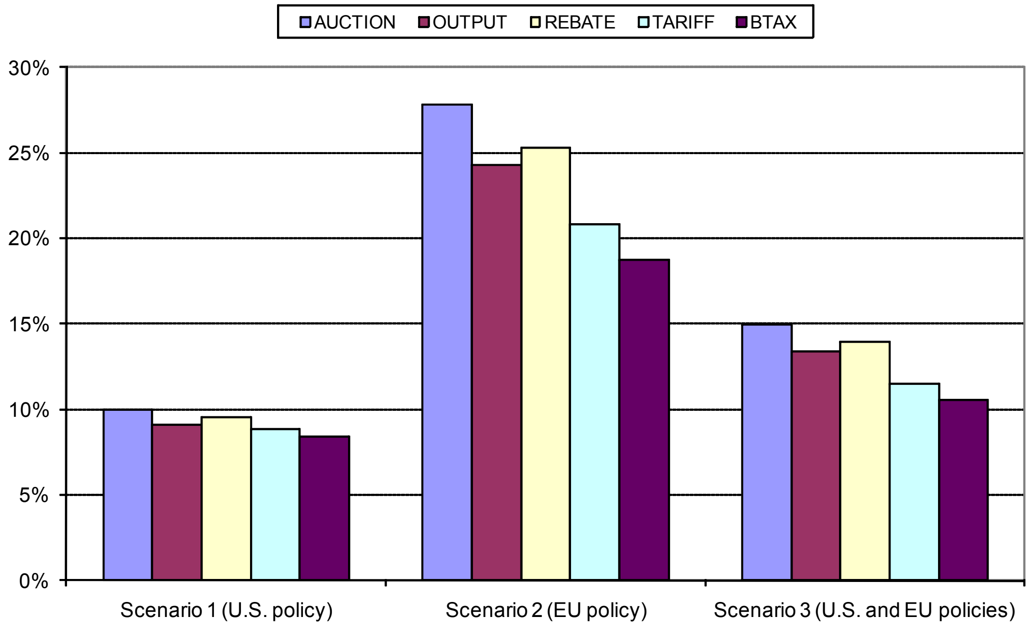


As already mentioned, subglobal climate policies in one or more regions typically lead to higher overall carbon emissions elsewhere. Leakage occurs not only through the international energy markets, as the drop in demand in the abating countries lowers global prices of fossil fuels, but also through the markets for energy-intensive goods, as the costs of producing such goods in the abating countries rise.

Figure 6 shows the size of global leakage in the policy scenarios. First, we observe that carbon leakage is highest when the European Union reduces its emissions. The leakage rate is then up to 28 percent, compared with up to 10 percent when the United States reduces its emissions. One reason for this difference is that the European Union is a more open economy than the United States, meaning that imports and exports constitute a larger share of the EU economy. This is true both for energy-intensive goods and for fossil fuels, of which the European Union is a much bigger importer (relative to own consumption) than the United States. This fact matters in particular for coal and gas, where transport costs are important, leading to differentiated prices around the world. Another reason for higher leakage with EU policies is that this region’s energy-intensive industries are less carbon-intensive than the same industries in the United States. Thus, relocation of industrial activities away from the abating region has more adverse effects on global emissions when the European Union imposes climate policies.

When both regions reduce emissions, the leakage rates are closer to the U.S. policy scenarios. This is partly because the United States has substantially higher emissions than the European Union, and partly because some of the leakages in Scenarios 1 and 2 take place in the European Union and the United States, respectively (see below). Thus, when both regions reduce their emissions, overall leakage tends to fall (which is obviously the case generally with increases in the regional coverage of subglobal action).

Figure 6. Global leakage effects of U.S. and/or EU CO_2 emissions reductions



Further, we see from Figure 6 that leakage differs little among the five alternative U.S. policies. This is not the case with the EU policies, however, where the differences in leakage are somewhat bigger across policy scenarios. The explanation is, again, that energy-intensive industries in the European Union are less carbon intensive than in the United States, and thus EU policies that prevent relocation of these industries to other regions produce less leakage. Moreover, the U.S. electricity sector has bigger potential for technology switching toward less carbon intensive technologies, and thus the relative emissions reduction in the power sector is bigger than in the European Union, which has relatively bigger emissions reductions in the energy-intensive industries. As a consequence, special treatment of these industries tends to have bigger effects on leakage in the European Union. Full border adjustment policies are most effective in reducing leakage, with the import tariff being more important than the export rebate. This is partly because the import tariff is the only instrument that can differentiate among regions, so that production of energy-intensive goods in regions with very carbon-intensive production is particularly penalized. Another reason is that even though output-based allocation, export rebates, and import tariffs all improve the competitiveness of domestic industries, the two former policies are subsidies to domestic production, whereas the latter policy is a tax on foreign production.

The figure further illustrates that border adjustment policies or output-based allocation can reduce carbon leakage to only a certain extent (by 33 percent, or nine percentage points, at most in these scenarios, when compared with the auction scenarios). The reason is that most of the carbon leakage in our study takes place via the international markets for fossil fuels: that is, lower consumption of oil and coal in the United States and the European Union leads to lower prices of these fuels, which in turn leads to increased demand for these fuels in other regions. The alternative policies are hardly able to deal with this sort of leakage (although import tariffs can to some degree, because foreign production is taxed).

Figure 7 shows how global leakage is distributed across regions in Scenarios 3A–3E. The share of global leakage that takes place in other OECD countries is 23 to 29 percent.[8] When only the United States reduces emissions, this share is in fact about 50 percent, and the European Union accounts for one-quarter of global leakage. On the other hand, EU policies have small leakage effects in the United States, and the OECD share of global leakage is then 25 to 30 percent. This difference is again due to the greater openness of the EU economy. A substantial share of leakage takes place in Russia. When we add Russia to the OECD countries, we approximate Annex B. The leakage to Annex B countries in Scenarios 3A–3E amounts to around 40 percent of global leakage.

Outside OECD and Russia, a large share of leakage occurs in Asian and African countries, whereas leakage to American countries is more moderate. African countries (outside OPEC) see significant increases in production of electricity and energy-intensive goods. The relative increases in such production in Asian countries are somewhat smaller, but the size of these countries is much bigger and hence the share of global leakage is larger.

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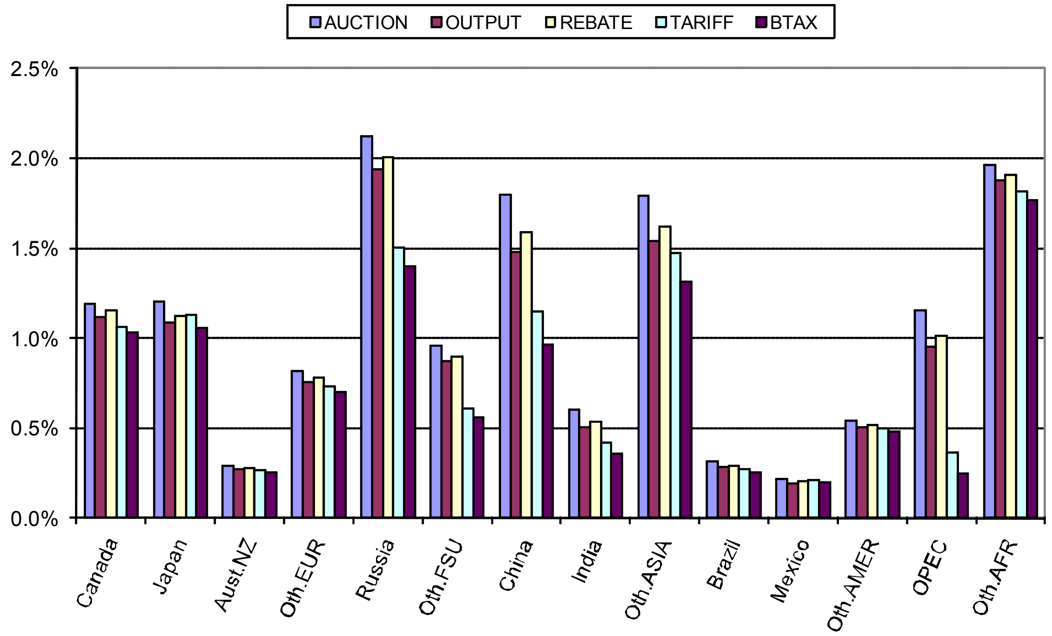
[8] This is seen by summing the leakage figures for Canada, Japan, Aust.NZ, and Oth.EUR and dividing by total leakage (shown in the last bars of Figure 5).

Figure 7. Leakage effects of U.S. and EU
CO_2 emissions reductions
(Scenarios 3A–3E)



If we look at the different policies, we observe that border adjustment policies and output-based allocation hardly reduce leakage to other OECD countries, and also to Latin American countries. The largest leakage effects are in Asian countries like China, former Soviet Union republics like Russia, and OPEC. These countries significantly increase their production and export of energy-intensive goods (particularly chemicals, iron and steel, and nonferrous metals) in the auction scenario, but less so under alternative policies (especially import tariffs).

The effects of unilateral climate policies on production of energy-intensive goods in the United States and the European Union are shown in Figure 8 and Figure 9. Production of chemical products, nonferrous metals, and (in the European Union) iron and steel are the most heavily affected, with reductions around 3 percent in the auction scenarios. Production of paper, pulp, and print has generally lower CO_2 intensities than the other energy-intensive industries. Mineral production like cement has substantial emissions of CO_2 but is less traded than the other goods because of higher transport costs.

Both output-based allocation and border adjustment policies dampen the production decrease. The policies have largest effects in the European Union

Both output-based allocation and border adjustment policies dampen the production decrease. The policies have largest effects in the European Union (Figure 9), consistent with the discussion of leakage, above. Full border adjustment policies (import tariffs and export rebate) are most effective in most cases, especially in the European Union. Overall, output-based allocation has about the same effect as import tariffs alone. All the policies have rather small effects on production of nonferrous metals (and paper, pulp, and print). The main explanation is that in the abating countries, these industries' heavy use of electricity becomes more costly, which the complementary policies do not target. If the import tariffs also take into account the indirect emissions (i.e., from electricity production) embodied in the products, production of nonferrous metals in the European Union will actually *increase* (not shown in the figure).

Figure 8. Effects of U.S. climate policies on U.S. production (Scenarios 1A–1E)

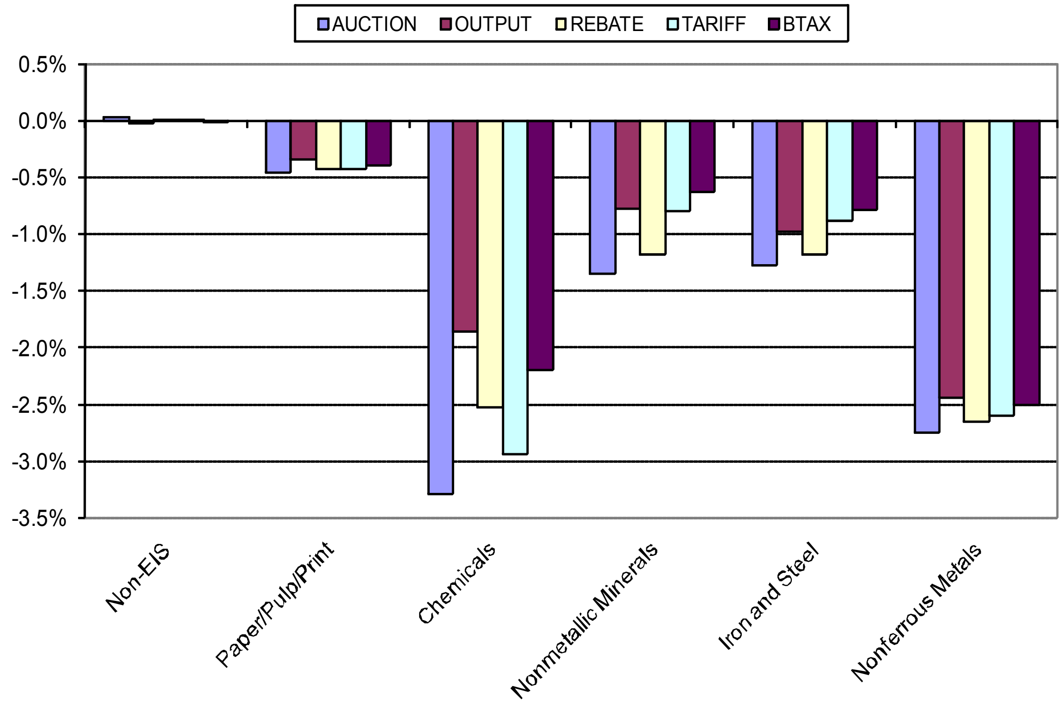
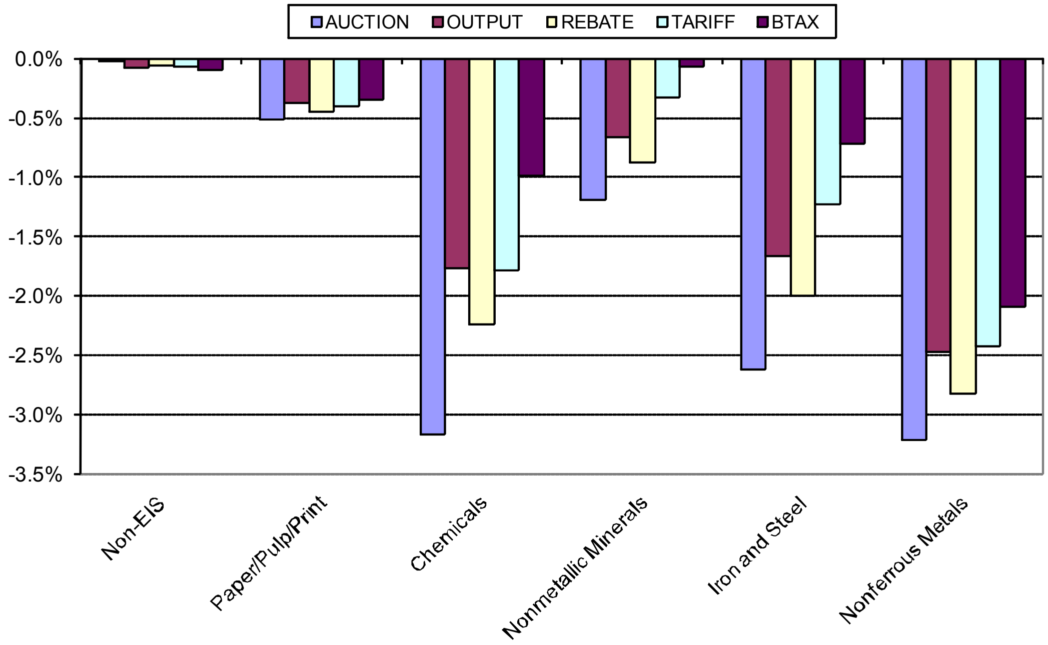


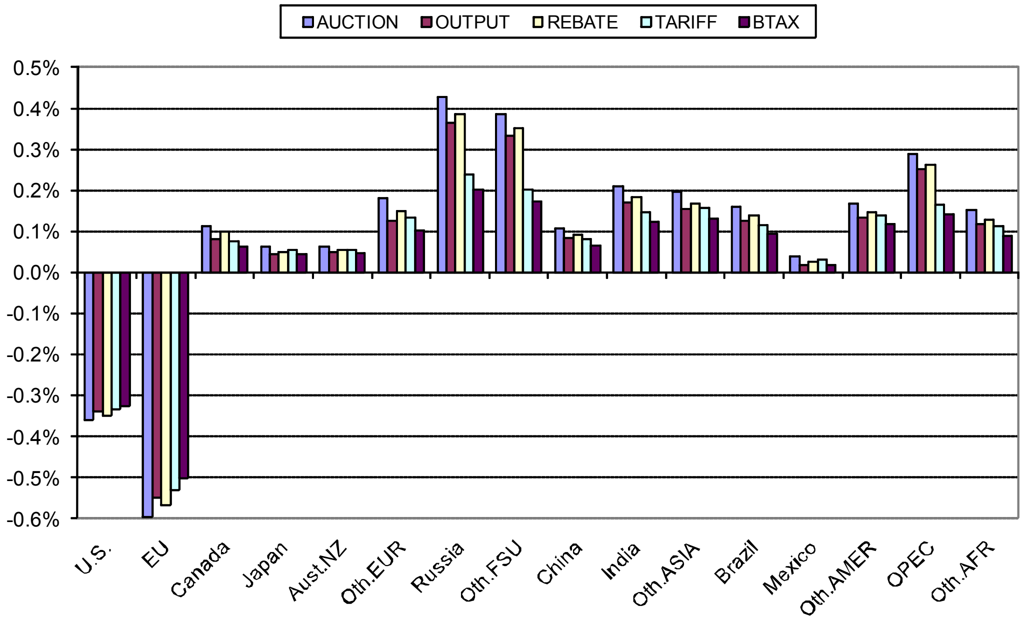
Figure 9. Effects of EU climate policies on EU production (Scenarios 2A–2E)



In Scenarios 3A–3E, when both the United States and the European Union cut emissions by 20 percent, the effects on production in the two regions are slightly smaller. In particular, the reductions in the United States are smaller when the European Union also cuts emissions. As noted above, U.S. climate policies have substantial consequences for the European Union, including its production of energy-intensive goods, but not so much the other way around. Thus, energy-intensive industries in the United States benefit more from EU policies than EU industries benefit from U.S. policies.

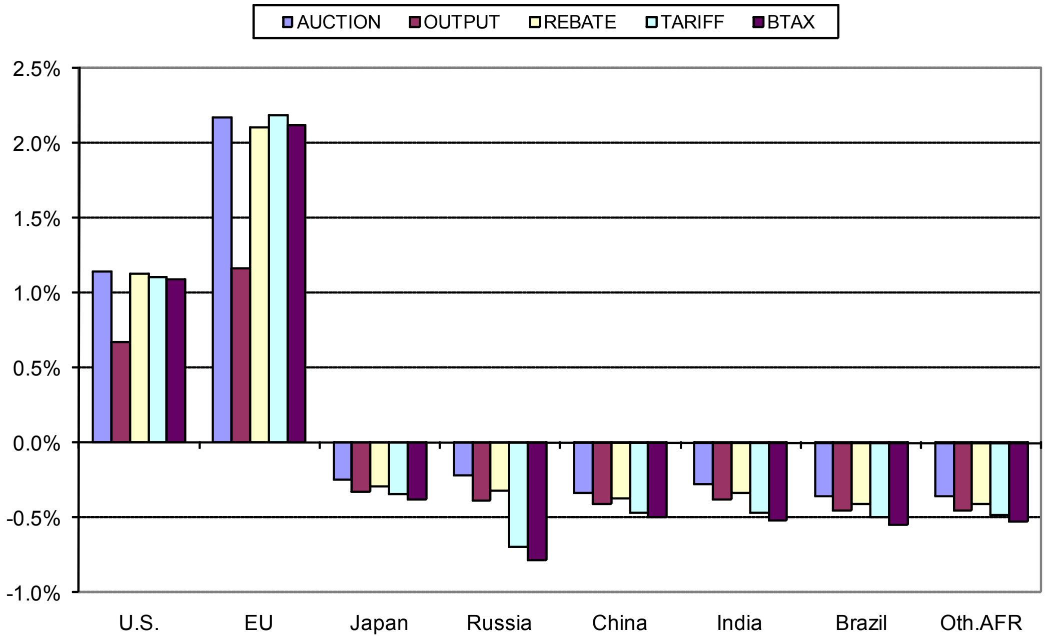
In the rest of the world, production in EIS increases across the board with the caps, while the OtherManuf&Serv sector (i.e., non-EIS, nonenergy, and nontransport) experiences production decreases in all countries except OPEC. The adjustment policies in part shift production in the other regions back toward non-EIS from EIS. Overall, however, aggregate production remains higher than with no climate policy action (Figure 10). By this metric, then, nonimplementing regions reap competitiveness benefits from the restrictions in the European Union and United States. Of course, in terms of consumption rather than production, they remain worse off, as shown earlier.

Figure 10. Percentage change in total production, by region (Scenarios 3A–3E)



The changes in prices of energy intensive goods in these countries tend to run counter to the production changes. Carbon pricing typically raises the domestic prices of energy-intensive products in the regulating countries; with (only) auctioning in the United States and the European Union, the prices of chemical, metal, and mineral products in these two regions increase by 1.2 to 2.4 percent. Output-based allocation, acting as an implicit output subsidy to these sectors, lowers the price increase by one-quarter to two-thirds. On the other hand, border adjustment policies have only small effects on these prices. For nonregulating trade partners, however, prices of these goods fall as global demand decreases and global energy prices adjust. Figure 11 gives as an example the relative price effects in the iron and steel sectors across a range of regions under different policy choices by the United States and European Union (Scenarios 3A–3E); the results for other EIS are similar. The regions included represent most of the major trading partners in EIS goods, covering the “BASIC” countries—Brazil, South Africa, India, and China—as well as Russia and Japan, in addition to the United States and European Union. For the nonregulating countries, auctioned allowances have the smallest effect on global steel prices. Output-based allocation lowers prices further, in nonregulating as well as regulating countries. The border adjustment scenarios have the largest downward effects on prices in partner countries, but the effects in the regulating countries are minimal.

Figure 11. Price effects of U.S. and EU climate policies on iron and steel sectors, across trading partners (Scenarios 3A–3E)



Figures 12–15 illustrate the effects of CO_2 emissions targets in both the United States and the European Union on exports of iron and steel, chemicals, nonferrous metals, and all energy-intensive goods, respectively, from these same countries.[9] To some degree, the results mirror the changes in production. In all auction cases, exports from these other countries increase, meaning that the changes in competitiveness outweigh the global demand reductions due to carbon pricing in the European Union and United States. All of the countervailing policies reduce these gains in exports in nonregulating countries to some extent and lessen the losses in the regulating countries. In no case do the European and United States experience increases in exports compared with no policy.

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[9] We focus on these products because their aggregation corresponds most closely to the energy-intensive products. Exports of paper, pulp, and print are only slightly changed by these policies, in part because the category is dominated by print.

We see some significant differences across regions and products. With full auction and no border adjustment policies, Asian countries see the highest relative increase in exports of chemical products and the lowest increase in exports of nonferrous metals. Other Africa sees the highest relative increase in exports of iron and steel products.

Output-based allocations and export rebates have quite similar effects across regions, with the former being somewhat more influential. These policies have small effects on exports of nonferrous metals, however, since we are not adjusting for the indirect emissions that are relatively important in these industries.

Figure 12. Changes in exports of iron and steel under U.S. and EU climate policies, by trading partner (Scenarios 3A–3E)

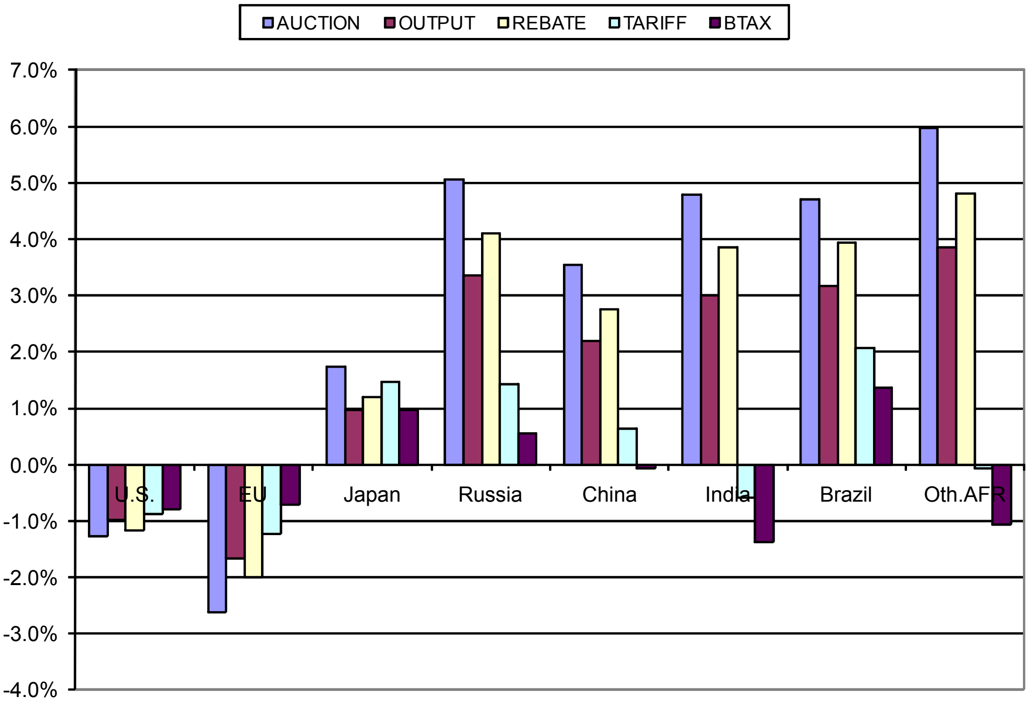


Figure 13. Changes in exports of chemicals under U.S. and EU climate policies, by trading partner (Scenarios 3A–3E)

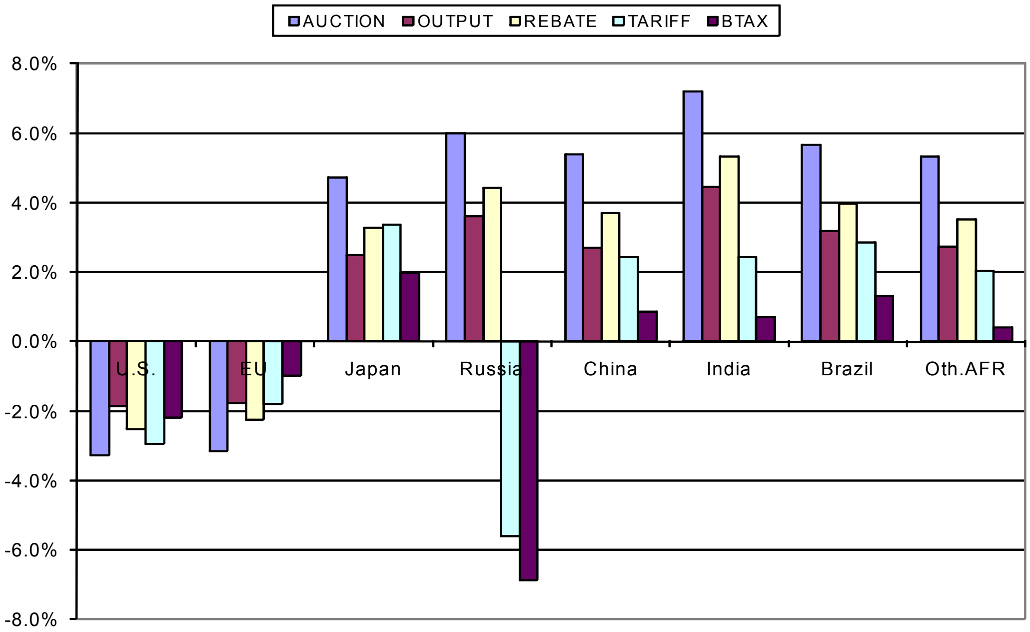


Figure 14. Changes in exports of nonferrous metals under U.S. and EU climate policies, by trading partner (Scenarios 3A–3E)

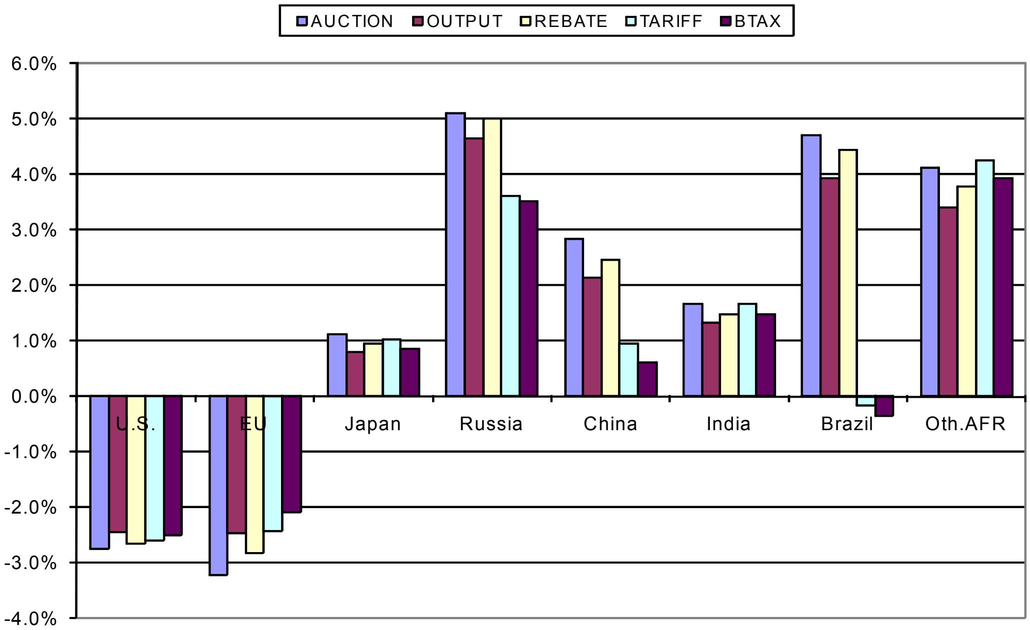
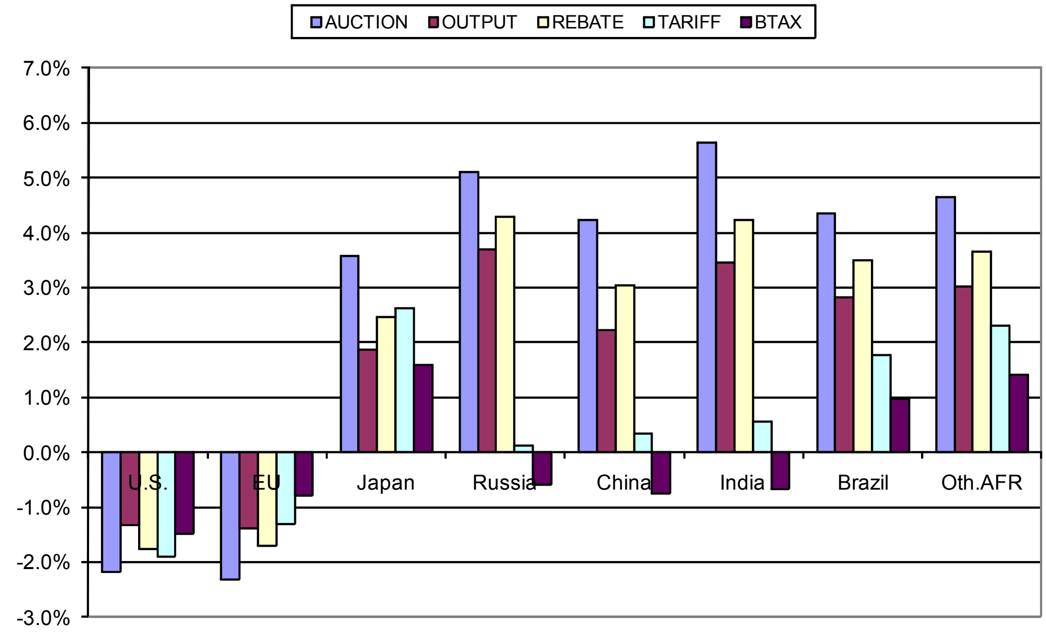


Figure 15. Changes in exports of all EIS products under U.S. and EU climate policies, by trading partner (Scenarios 3A–3E)



Import tariffs (and full border adjustment) have stronger effects on exports from these regions; still, in most cases, their exports are still higher with import tariffs in the United States and the European Union than without any climate policy whatsoever. The exceptions in this country sample are Russia, driven by the chemicals sector, and China and India, driven by nonmetallic minerals (in which exports experience a 10–12 percent drop with border adjustments). Import tariffs have much more differentiated effects across regions and sectors. The explanation is, of course, that the tariff treats imports from different regions differently, based on the embodied carbon in that region. Carbon intensities vary substantially across regions for all energy-intensive products. For instance, the carbon intensity of Brazilian production of nonmetallic minerals is several times smaller than the corresponding carbon intensity in China. And Japan has the smallest carbon intensity in production of iron and steel and nonferrous metals of the regions presented in these figures. The large variation in carbon intensities occurs partly because the five sectors in reality consist of a much larger number of subsectors producing different products with different carbon intensities. In addition, different regions use different technologies with different inputs of energy to produce the same product.

Conclusions

We find that the welfare effects of subglobal climate policies are significant not only for the countries undertaking them but also for their trade partners, who experience changes in demand for their products as well as changes in global energy prices. In some cases, the welfare losses (in terms of percentage changes in consumption) can be even larger abroad than at home, particularly for fossil fuel producers. When the United States is reducing its emissions, however, a few trade partners gain, including Japan, India, and Canada.

Policies intended to avoid leakage have little effect on welfare overall—even in the countries implementing them—because they mostly just shift global production in certain energy-intensive goods. Although these additional welfare changes are small, implementing countries do benefit from adjustment policies, while most nonimplementing countries (particularly developing ones) would prefer no adjustment; the net effect of antileakage policies is a slight reduction in the global costs of achieving a given level of emissions reductions.

Regarding leakage, we find that a significant share of leakage occurs via changes in global energy prices. Hence, none of the countervailing policies reduce leakage rates very much—at most by 22 percent, in the case of full border adjustments. Furthermore, 40 percent of leakage from U.S. and EU climate policies can be attributed to other Annex B nations.

Policies like output-based rebates and border adjustments do have significant effects on the energy-intensive sectors to which they are applied. Domestic production changes are mitigated and foreign exports are also reduced. Still, for the most part, domestic production is lower and foreign production and exports are higher than without any climate policy intervention. One exception in our modelling results is that full border adjustment can cause exports from other countries to decrease below baseline levels, particularly in the nonmetallic minerals sector.

The narrow debate about border adjustments may prove to be a tempest in a teapot that is being tossed around in a much larger tempest. Clearly, the main effects on global welfare, emissions, and leakage arise from the primary climate policies themselves. Developed countries should understand that most developing nations do not actually gain economically from the former's efforts to reduce greenhouse gas emissions. At the same time, developing countries should recognize that their sectors targeted specifically by antileakage policies do not necessarily lose, compared with a world without any climate policies. Ultimately, it is in all countries' interest to mitigate climate change as comprehensively and cost-effectively as possible, and the larger question is whether unilateral antileakage policies can help in the transition to concerted global action.

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