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Climate Change, Trade, and Competitiveness

Is a Collision Inevitable?

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WARWICK J. MCKIBBIN
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The Economic and Environmental Effects of Border Tax Adjustments for Climate Policy

For the foreseeable future, climate change policy will be considerably more stringent in some countries than in others. Indeed, the United Nations Framework Convention on Climate Change explicitly states that developed countries must take meaningful action before any obligations are to be placed on developing countries.

However, differences in climate policy will lead to differences in energy costs, and to concerns about competitive advantage. In high-cost countries, there will be political pressure to impose border tax adjustments (BTAs), or "green tariffs," on imports from countries with little or no climate policy and low energy costs. The BTAs would be based on the carbon emissions associated with the production of each imported product, and they would be intended to match the cost increase that would have occurred had the exporting country adopted a climate policy similar to that of the importing country.

Several justifications have been proposed for including BTAs as a key component of climate policy. Some researchers—including Stiglitz, Kopp and Pizer, and Ismer and Neuhoff—argue that BTAs are required for economic efficiency in carbon abatement.[1] An alternative argument is that BTAs are needed to keep climate policy from being undermined by the "leakage" of emissions through migration of carbon-intensive industries to low-tax countries and, as a corollary, to protect import-competing industries in high-tax countries.[2] There are also a number of papers that argue that the approach could be used to punish countries that did not participate in the Kyoto Protocol, or could be used as a threat to encourage recalcitrant countries to join a global regime.[3] Finally, there

The authors thank Nils Axel Braathen, Lael Brainard, Isaac Sorkin, and participants in the conference where this chapter was first presented for helpful comments.

1. See Stiglitz (2006); Kopp and Pizer (2007); Ismer and Neuhoff (2007).
2. For example, see Goh (2004); Hoerner (1998); Demailly and Quirion (2006); Babiker and Rutherford (2005).
3. For example, see Brack, Grubb, and Windram (2000); Hontelez (2007); and the discussion in Charnovitz (2003).

is also a considerable literature debating the legality of BTAs for climate polices under World Trade Organization rules.[4]

These arguments are reflected in the political debate in Europe and the United States. In 2006 then–French prime minister Dominique de Villepin suggested that countries that do not join a post-2012 international treaty on climate change should face additional tariffs on their industrial exports. The European Parliament's (2005/2049) resolution was focused on penalizing countries such as the United States for nonparticipation in the Kyoto Protocol. In the United States, both the Bingaman-Specter Bill (S 1766) and the Leiberman-Warner Bill (S 2191) include mechanisms that would, in effect, impose BTAs under some circumstances for imported goods from countries deemed to be making insufficient effort to reduce their greenhouse gas emissions.[5]

Most of the arguments in the literature, however, have been theoretical. Little empirical work has been done to determine either the magnitude that BTAs would take in practice, or on the economic and environmental consequences they would cause. This gap leads to a range of important questions. Would BTAs actually improve global carbon abatement? How much would they help or hurt the economy of the country imposing them? How much would they help or hurt the global economy? Are the gains, if any, large enough to justify the administrative costs involved? In this chapter, we address several of these questions. We estimate how large such tariffs would be in practice,[6] and then examine their economic and environmental effects using G-Cubed, a detailed multisector, multicountry model of the world economy.[7] We find that the tariffs would be small on most traded goods, would reduce leakage of emissions reduction very modestly, and would do little to protect import-competing industries. We conclude that the benefits produced by BTAs would be too small to justify their administrative complexity or their deleterious effects on international trade and the potentially damaging consequences for the robustness of the global trading system.[8]

In a sense, these results are not surprising, because most carbon emissions are from domestic activities, such as electricity generation and local and regional

4. See Biermann and Brohm (2005); Brewer (2008); Frankel (2005); Goh (2004); Hoerner (1998).

5. See the discussion in Brewer (2008).

6. This chapter focuses only on import adjustment. For a discussion of the problems that arise with adjustment to exports in order to maintain competitiveness, see Pearce and McKibbin (2007).

7. Other studies, such as Levinson and Taylor (2008), have used an econometric approach to examine a related issue, the "pollution haven hypothesis," to determine whether differences in historical environmental regulation have caused industries to migrate between countries. Our results, which examine prospective regulations using an econometrically estimated structural model and simulation analysis, produces results that are broadly consistent with that literature.

8. These results of the damaging effect on trade are also found in Droge and Kemfert (2005).

transportation, which are largely nontraded and are little affected by international trade.[9] In practice, the most important mechanism through which leakage could occur would be world oil markets, not trade in manufactured goods. A sufficiently large carbon tax imposed in a major economy would lower global oil prices and lead to higher consumption in countries with little or no carbon tax. However, BTAs would be neither appropriate nor effective in reducing that form of leakage. We conclude that it is an unnecessary distraction for the global community to focus much attention on negotiations over BTAs as a component of climate policy; they would not matter much in practice and, as also argued by Lockwood and Whalley, they may lead to greater distortions to the global trading system.[10]

An Overview of the G-Cubed Model

G-Cubed is an econometric intertemporal general equilibrium model of the world economy with regional disaggregation and sectoral detail. For this chapter, the world economy is divided into the ten regions shown in table 1-1. Each region is further decomposed into a household sector, a government sector, a financial sector, the twelve industrial sectors shown in table 1-2, and a capital-goods-producing sector. To facilitate the analysis of energy and environmental policy, five of the industries are used to represent segments of the energy industry: electric utilities, natural gas utilities, petroleum refining, coal mining, and crude oil and gas extraction. All regions are linked through bilateral trade in goods and financial assets. All relevant budget constraints are imposed on households, governments, and nations (the latter through accumulations of foreign debt). Households and firms have forward-looking expectations and use those projections when planning consumption and investment decisions. However, a portion of the households and firms are assumed to be liquidity constrained. G-Cubed is a very large example of the dynamic stochastic general equilibrium models used in the macroeconomics literature. It is also an intertemporal general equilibrium model from the computable general equilibrium class of models. We have described G-Cubed's theoretical and empirical structure in more detail elsewhere.[11] In the remainder of this section, we present a brief summary of its key features.

9. This point on the scale of leakage was made in McKibbin and Wilcoxen (1997).
10. Lockwood and Whalley (2008).
11. McKibbin and Wilcoxen (1998).

Table 1-1. Regions in the G-Cubed Model

1	United States
2	Japan
3	Australia
4	Europe
5	Other members of Organization for Economic Cooperation and Development (OECD)
6	China
7	India
8	Other developing countries (LDCs)
9	Eastern Europe and the former USSR (EEFSU)
10	Oil-exporting developing countries (members of the Organization of the Petroleum Exporting Countries, OPEC)

Table 1-2. Industrial Sectors in the G-Cubed Model

1	Electric utilities	7	Agriculture
2	Gas utilities	8	Forestry and wood products
3	Petroleum refining	9	Durable goods
4	Coal mining	10	Nondurables
5	Crude oil and gas extraction	11	Transportation
6	Other mining	12	Services

Producer Behavior

Each producing sector in each region is modeled by a representative firm, which chooses its inputs and its level of investment to maximize its stock market value subject to a multiple-input constant elasticity of substitution production function and a vector of prices it takes to be exogenous. We assume that output is produced using inputs of capital, labor, energy, and materials. Energy and materials, in turn, are aggregates of inputs of intermediate goods and services.

We assume that all regions share production methods that differ in first-order properties but have identical second-order characteristics. This is intermediate between the extremes of assuming that the regions share common technologies and of allowing the technologies to differ across regions in arbitrary ways.[12] Finally, the regions also differ in their endowments of primary factors and patterns of final demands.

Maximizing the firm's short-run profit subject to its capital stock and its production function gives the firm's factor demand equations. At this point, we

12. We adopt this approach because estimation of the second-order parameters requires a time series of input/output tables. Outside OECD countries there are generally too few tables available to permit the coefficients to be estimated separately for each country.

add two further levels of detail: We assume that domestic and imported inputs of a given commodity are imperfect substitutes, and that imported products from different countries are imperfect substitutes for each other. Thus, the final decision the firm must make is the fraction of each of its inputs to buy from each region in the model (including the firm's home country). We assume that all agents in each economy have identical preferences over foreign and domestic varieties of each particular commodity.[13] The result is a system of demand equations for domestic goods and imports from every region.

In addition to buying inputs and producing output, each sector must also choose its level of investment. We assume that capital is specific to each sector, that investment is subject to adjustment costs, and that firms choose their investment paths to maximize their market value. In addition, each industry faces the usual constraint on its accumulation of capital that the change in the capital stock is equal to gross investment less depreciation.

Following the cost of adjustment models of Lucas, Treadway, and Uzawa, we assume that the investment process is subject to rising marginal costs of installation.[14] Setting up and solving the firm's investment problem yields an investment decision that depends on production parameters, taxes, the current capital stock, and marginal q (that is, the ratio of the marginal value of a unit of capital to its purchase price).

Following Hayashi, we modify the investment function to improve its empirical properties by writing it as a function not only of q but also of the firm's current capital income.[15] This improves the empirical behavior of the specification and is consistent with the existence of firms that are unable to borrow and therefore invest purely out of retained earnings. The fraction of fully optimizing firms is taken to be 0.3 based on a range of empirical estimates;[16] the fraction that are liquidity constrained is 0.7.

In addition to the twelve industries discussed above, the model also includes a special sector that produces capital goods. This sector supplies the new investment goods demanded by other industries. Like other industries, the investment sector demands labor and capital services as well as intermediate inputs. We represent its behavior using a nested constant elasticity of substitution production function with the same structure as that used for the other sectors. However, we estimate the parameters of this function from price and quantity data for the final demand column for investment.

13. Anything else would require time-series data on imports of products from each country of origin to each industry, which is not only unavailable but difficult to imagine collecting.

14. Lucas (1967); Treadway (1969); Uzawa (1969).

15. Hayashi (1979).

16. These empirical estimates are reported by McKibbin and Sachs (1991).

Households and Governments

Households consume a basket of composite goods and services in every period and also demand labor and capital services. Household capital services consist of the service flows of consumer durables and residential housing. Households receive income by providing labor services to firms and the government, and from holding financial assets. In addition, they receive imputed income from ownership of durables and housing, and they also receive transfers from their region's government.

Within each region, we assume household behavior can be modeled by a representative agent who maximizes an intertemporal utility function subject to the constraint that the present value of consumption is equal to the sum of human wealth and initial financial assets. Human wealth is the present value of the future stream of after-tax labor income and transfer payments received by households. Financial wealth is the sum of real money balances, real government bonds in the hands of the public,[17] net holdings of claims against foreign residents, and the value of capital in each sector.

There has, however, been considerable debate about whether the actual behavior of aggregate consumption is consistent with the permanent income model.[18] On the basis of the evidence cited by Campbell and Mankiw,[19] we modify the basic household model described above to allow a portion of household consumption to depend entirely on current after-tax income (rather than on wealth). This could be interpreted in various ways, including the presence of liquidity-constrained households or households with myopic expectations. For the purposes of this chapter, we will not adopt any particular explanation and will simply take the income-driven share of consumption to be an exogenous constant. Following McKibbin and Sachs, we take the share to be 0.7 in all regions.[20]

Within each period, the household allocates expenditures among goods and services to maximize its intratemporal utility. In this version of the model, we assume that intratemporal utility may be represented by a Cobb-Douglas function of goods and services.[21] Finally, the supply of household capital services is determined by consumers themselves, who invest in household capital. We

17. Ricardian neutrality does not hold in this model because some consumers are liquidity-constrained.

18. Some of the key papers in this debate are Hall (1978); Flavin (1981); Hayashi (1982); and Campbell and Mankiw (1990).

19. Campbell and Mankiw (1990).

20. McKibbin and Sachs (1991). Our income-driven faction is somewhat higher than Campbell and Mankiw's estimate of 0.5.

21. This specification has the undesirable effect of imposing unitary income and price elasticities.

assume that households choose their level of investment to maximize the present value of future household capital service flows (taken to be proportional to the household capital stock), and that investment in household capital is subject to adjustment costs. In other words, the household investment decision is symmetrical with that of the firms.

Government

We take each region's real government spending on goods and services to be exogenous and assume that it is allocated among final goods, services, and labor in fixed proportions according to the base year input/output table for each region. Total government spending includes purchases of goods and services plus interest payments on government debt, investment tax credits, and transfers to households. Government revenue comes from sales, corporate, and personal income taxes and from the issuance of government debt. In addition, there can be taxes on externalities such as carbon dioxide emissions. We assume that agents will not hold government bonds unless they expect the bonds to be serviced. Accordingly, we impose a transversality condition on the accumulation of public debt in each region that has the effect of causing the stock of debt at each point in time to be equal to the present value of all future budget surpluses from that time forward. This condition alone, however, is insufficient to determine the time path of future surpluses: The government could pay off the debt by briefly raising taxes a lot; it could permanently raise taxes a small amount; or it could use some other policy. We assume that the government levies a lump sum tax in each period equal to the value of interest payments on the outstanding debt. In effect, therefore, any increase in government debt is financed by Consols (that is, bonds without a redemption date that pay interest in perpetuity), and future taxes are raised enough to accommodate the increased interest costs. Thus, any increase in the debt will be matched by an equal present value increase in future budget surpluses.

Macroeconomic Features: Labor Market Equilibrium and Money Demand

We assume that labor is perfectly mobile among sectors within each region but is immobile between regions. Thus, within each region, wages will be equal across sectors. The nominal wage is assumed to adjust slowly according to an overlapping contracts model, where nominal wages are set based on current and expected inflation and on labor demand relative to labor supply. In the long run, labor supply is given by the exogenous rate of population growth; but in the short run, the hours worked can fluctuate depending on the demand for labor.

For a given nominal wage, the demand for labor will determine short-run unemployment.

Relative to other general equilibrium models, this specification is unusual in allowing for involuntary unemployment. We adopted this approach because we are particularly interested in the transition dynamics of the world economy. The alternative of assuming that all economies are always at full employment, which might be fine for a long-run model, is clearly inappropriate during the first few years after a shock.

Finally, because our wage equation depends on the rate of expected inflation, we need to include money demand and supply in the model. We assume that money demand arises from the need to carry out transactions and depends positively on aggregate output and negatively on the interest rate. The supply of money is determined by the balance sheet of the central bank and is exogenous.

International Trade and Asset Flows

The regions in the model are linked by flows of goods and assets. Each country's exports are differentiated from those of other countries; exports of durables from Japan, for example, are not perfect substitutes for exports of durables from Europe. Each region may import each of the twelve goods from potentially all the other regions. In terms of the way international trade data are often expressed, our model endogenously generates a set of twelve bilateral trade matrices, one for each good. The values in these matrices are determined by the import demands generated within each region.

Trade imbalances are financed by flows of assets between countries. We assume that asset markets are perfectly integrated across the regions and that financial capital is freely mobile.[22] Under this assumption, expected returns on loans denominated in the currencies of the various regions must be equalized period to period according to a set of interest arbitrage relations. In generating the baseline of the model, we allow for risk premiums on the assets of alternative currencies, although in counterfactual simulations of the model, these risk premiums are generally assumed to be constant and unaffected by the shocks we consider.

22. The mobility of international capital is a subject of considerable debate; see Gordon and Bovenberg (1996) or Feldstein and Horioka (1980). Also, this assumption should not be confused with our treatment of physical capital, which we assume to be specific to sectors and regions and hence completely immobile. The consequence of assuming mobile financial capital and immobile physical capital is that there can be windfall gains and losses to owners of physical capital. For example, if a shock adversely affects profits in a particular industry, the physical capital stock in that sector will initially be unaffected. Its value, however, will immediately drop by enough to bring the rate of return in that sector back into equilibrium with that in the rest of the economy.

For all regions other than China, we assume that exchange rates are free to float and that financial capital is freely mobile. This may appear less plausible for developing countries than it does for countries that belong to the Organization for Economic Cooperation and Development (OECD), because many developing countries have restrictions on short-term flows of financial capital. However, the capital flows in our model are the sum of short-term portfolio investment and foreign direct investment, and the latter is usually subject to fewer restrictions. In many countries with constraints on financial instruments, there are large flows of direct foreign investment responding to changes in expected rates of return. We assume that China pegs its exchange rate to the dollar, with a slight adjustment for deviations in output growth from trend and actual inflation from the desired target rate. This is closer to the recent historical record than the alternative assumptions of floating exchange rates or exactly fixed exchange rates.

Calculating the Carbon Content of Traded Goods

In general, BTAs are used to compensate for differences between countries in the taxes levied on goods, such as excise taxes or value-added taxes. Exporting countries may exempt traded goods from such taxes, or rebate taxes already collected, and importing countries may impose taxes equivalent to what would have been charged had the product been produced domestically. In this chapter, we examine only adjustments on imports and assume that carbon taxes are not rebated on exports. However, our methodology could be applied to export rebates as well.

The first step in computing a carbon-tax BTA on a given import would be to determine the total amount of fossil energy that was used directly or indirectly in the production of the good. Measuring direct energy consumption is relatively straightforward; an aircraft, for example, requires the direct use of energy when it is assembled. However, energy is also used indirectly through the production of all the parts and materials from which the plane is made. Computing total indirect energy consumption requires following the value-added chain back through intermediate products at every stage: Energy is used to produce sheet metal from aluminum; to produce aluminum from bauxite; and to mine the bauxite itself.

Tracing energy consumption all the way back to raw materials is possible using input/output tables. An input/output "use" table is a matrix showing the flow of each good to each industry in a particular year. Using that information, it is possible to determine the amount of each input needed to make a single unit of output. If A is a matrix of such coefficients, with one row for each input and one column for each output, the set of market equilibria for the inputs can be summarized in equation 1, where X is a vector of gross outputs by commodity, and F is a vector of final demands:

$$AX + F = X \tag{1}$$

The left side is total demand for each product: AX is the demand for intermediate goods, and F is final demand. The right side, X, is the supply of each good. Solving for X gives the total input needed to produce any given final demand vector:

$$X = (I - A)^{-1}F \tag{2}$$

Matrix $(I - A)^{-1}$ is known as a "total requirements" table. Each row corresponds to an input and each column to an output, and each element shows the amount of the input used directly or indirectly in the production of one unit of the output. For example, the total amount of coal consumption that can be attributed to production of a durable good would appear as an element in the coal row and durable goods column of $(I - A)^{-1}$.

Computing the implicit carbon content of each product requires two additional steps: The inputs of each fossil fuel are multiplied by appropriate emissions coefficients to convert fuel consumption to carbon emissions, and then carbon emissions are summed across fuels. The result is a single coefficient for each good giving the total carbon emissions that can be attributed to the good's production.

Because input/output tables are used in the construction of G-Cubed, the information needed to compute a total requirements table for each region in the model was readily available. In addition, the model's database includes emissions coefficients for each fuel, with emissions in millions of metric tons of carbon for each of the model's units of fuel, so the final steps were straightforward as well. Carrying out the calculation produced the results are shown in table 1-3. For convenience, the results are shown as thousands of metric tons. As indicated in the lower rows of the table, production of nonfuel traded goods generally involves emissions of 0.1 to 1.1 thousand metric tons per model unit of output. (The model's output units are large, corresponding to billions of dollars of output in a base year.) For example, one unit of durable goods produced in the United States is associated with 0.13 thousand metric tons of carbon. Implicit emissions vary strongly across regions; emissions associated with durables are only 0.7 thousand metric tons per unit in Japan, but are 1.01 thousand tons per unit in China. As expected, Japan and Europe are most efficient in terms of carbon and have the lowest coefficients; the highest coefficients are associated with China, India, and Eastern Europe and the former Soviet Union.

Table 1-3. Carbon Content of Nonfuel Exports by Country or Region of Origin

Thousands of metric tons of carbon per model unit

Export Sector	*United States*	*Japan*	*Australia*	*Europe*	*Other OECD Members*	*China*	*India*	*Less-Developed Countries*	*Former USSR*	*OPEC*
Electric utilities	2.65	0.38	2.76	0.60	1.45	7.63	4.98	2.07	4.27	1.05
Gas utilities	0.41	0.65	1.07	0.13	0.70	11.68	0.37	1.55	1.25	0.17
Petroleum refining	6.59	1.75	3.53	1.75	4.37	7.38	4.94	5.30	6.82	2.45
Coal	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Crude oil	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Mining	0.27	0.10	0.35	0.21	0.87	0.81	1.20	0.41	0.98	0.15
Agriculture	0.17	0.10	0.16	0.13	0.25	0.47	0.36	0.20	0.84	0.07
Forestry and wood	0.13	0.05	0.21	0.08	0.18	0.61	0.24	0.16	1.01	0.08
Durables	0.13	0.07	0.43	0.09	0.23	0.97	1.01	0.33	1.10	0.21
Nondurables	0.23	0.13	0.23	0.15	0.33	0.92	0.81	0.37	1.06	0.21
Transportation	0.22	0.08	0.25	0.18	0.32	0.87	0.59	0.35	1.08	0.20
Services	0.05	0.04	0.09	0.03	0.11	0.59	0.30	0.13	0.71	0.08

Source: Authors' calculations.

Note: OECD = Organization for Economic Cooperation and Development; OPEC = Organization of the Petroleum Exporting Countries; N.A. = not applicable.

Table 1-4. Carbon Tax and Border Tax Adjustment Simulations

Name	*Description*
EU-Tax	European carbon tax without BTAs
EU-TaxAdj	European integrated carbon tax and BTA policy
US-Tax	U.S. carbon tax without BTAs
US-TaxAdj	U.S. integrated carbon tax and BTA policy

Carbon Taxes with and without Border Tax Adjustments

This section describes the simulations we ran using the G-Cubed model to explore the effects of BTAs. We began by constructing a hypothetical carbon tax beginning at $20 per metric ton of carbon dioxide and rising by $0.50 per year to $40. The tax was intended to illustrate the effect of BTAs over a range of carbon prices but was not designed to achieve any specific emissions target. Our results would apply to a tradable permit policy as well, if the policy had similar equilibrium permit prices. However, administering the BTAs would be much more difficult under a permit system, because frequent revisions would be needed to follow fluctuations in the permit price.

We then examined the effects of the carbon tax under four scenarios about its implementation: (1) It is adopted in Europe without BTAs (referred to in the tables below as "EU-Tax"); (2) it is adopted in Europe, and BTAs are imposed on imports to Europe, assuming that the carbon embodied in the imports matches the energy intensity of the United States ("EU-TaxAdj"); (3) the tax is adopted in the United States without BTAs ("US-Tax"); and (4) it is adopted in the United States, and BTAs are imposed based on the energy intensity of China ("US-TaxAdj"). These simulations, which are descriptively summarized in table 1-4, were chosen to contrast the effects of BTAs between countries with similar and relatively efficient technology, Europe and the United States, with the effects of BTAs between countries with more heterogeneous technology, the United States and China.

In all four simulations, additional government revenue generated by the BTAs and the carbon tax itself was used to finance additional government spending in the corresponding region (that is, each region's fiscal deficit was held constant). Other fiscal assumptions could be used instead; for example, the revenue could be used to lower the deficit, or it could be returned to households via a lump-sum rebate.

The BTAs were computed by multiplying the embodied carbon per unit of output by the carbon tax prevailing in each year, and then converting the result to an ad valorem rate.[23] No adjustments were applied to imports of coal and crude petroleum, which are already subject to the carbon tax, which was applied to imports as well as domestic production. The results are shown in tables 1-5 and 1-6 for two carbon tax rates: \$20 and \$40 per ton. For the European tariffs shown in table 1-5, the rates for the \$20 tax are small: less than 1 percent for tradable goods other than fuels. The rates for the \$40 tax are twice as large, but still small; the largest are the tax on nondurables, at 0.92 percent, and on transportation, at 0.88 percent. For the U.S. tariffs shown in table 1-6, the rates are considerably higher. When the carbon tax is \$20 per ton, the effective tariffs on durable and nondurable manufactured goods are almost 2 percent. At the \$40 per ton rate, the tariffs double to slightly less than 4 percent. The rates in table 1-6 reflect the higher energy intensity of Chinese manufacturing, as was shown in table 1-3.

The effects of the two European scenarios on real gross domestic product (GDP) are shown in table 1-7. The carbon tax lowers European GDP by 0.6 to 0.7 percent. Lower European GDP, in turn, lowers GDP in Eastern Europe and the former Soviet Union (EEFSU) by 0.1 to 0.2 percent. OPEC's GDP also falls slightly, but the remaining countries and regions are affected by less than 0.1 percent. Adding BTAs has little additional effect on the European GDP, which is still reduced by 0.6 to 0.7 percent. However, the GDP of the EEFSU region drops considerably more than under the carbon tax alone: 0.5 to 0.7 percent. In part, this is due to the increase in trade barriers between Europe and the EEFSU; even though the BTA rates are calculated based on U.S. energy intensities, in this simulation they are applied to European imports.

The effects of the policies on annual carbon emissions from each region are shown in table 1-8. The carbon tax alone lowers European emissions by 53 to 98 million metric tons (mmt) per year over the 2010–30 period. Some of these emissions are offset by increases in other regions, often referred to as "leakage." In 2010, for example, European emissions fall by 53 mmt but world emissions fall by only 48 mmt. The difference is 5 mmt, or about 10 percent of the European decrease: 2 mmt in the United States, 1 mmt in developing countries, and 2 mmt in EEFSU. Adding BTAs causes a larger reduction in worldwide emissions: 69 to 127 mmt annually over the period. The larger cuts are the result of three interacting effects: European emissions do not fall as much (49 to 91 mmt), there is no leakage of emissions to the United States or less-developed countries, and the EEFSU's emissions fall by much more due to the much larger drop in the EEFSU's GDP.

23. The conversion to an ad valorem rate was for convenience; in practice, it is likely that a unit tax would be used.

Table 1-5. Simulated European Border Tax Adjustments Based on U.S. Energy Intensity

Percentage point change in ad valorem tariff

Sector	*$20 per ton carbon tax*	*$40 per ton carbon tax*
Electric utilities	5.30	10.60
Gas utilities	0.82	1.64
Petroleum refining	13.18	26.36
Coal	N.A.	N.A.
Crude oil	N.A.	N.A.
Mining	0.54	1.08
Agriculture	0.34	0.68
Forestry and wood	0.26	0.52
Durables	0.26	0.52
Nondurables	0.46	0.92
Transportation	0.44	0.88
Services	0.10	0.20

Source: Authors' calculations.
Note: N.A. = not applicable.

Table 1-6. Simulated U.S. Border Tax Adjustments Based on China's Energy Intensity

Percentage point change in ad valorem tariff

Sector	*$20 per ton carbon tax*	*$40 per ton carbon tax*
Electric utilities	15.26	30.52
Gas utilities	23.36	46.72
Petroleum refining	14.76	29.52
Coal	N.A.	N.A.
Crude oil	N.A.	N.A.
Mining	1.62	3.24
Agriculture	0.94	1.88
Forestry and wood	1.22	2.44
Durables	1.94	3.88
Nondurables	1.84	3.68
Transportation	1.74	3.48
Services	1.18	2.36

Source: Authors' calculations.
Note: N.A. = not applicable.

Table 1-9 shows the effects of the two policies on short-run interest rates in each region. Both policies lower the return to capital in Europe, and to a lesser extent, the EEFSU. The changes in interest rates in other regions are generally very small. Lower rates of return in Europe and the EEFSU lead to capital outflows and shifts of the two regions' trade and current account balances toward surplus, as shown in tables 1-10 and 1-11. The capital flows to the remaining regions in the model, which generally see their trade and current accounts shift

Based on U.S. Energy Intensity

$40 per ton carbon tax
10.60
1.64
26.36
N.A.
N.A.
1.08
0.68
0.52
0.52
0.92
0.88
0.20

on China's Energy Intensity

$40 per ton carbon tax
30.52
46.72
29.52
N.A.
N.A.
3.24
1.88
2.44
3.88
3.68
3.48
2.36

ɔn short-run interest rates in
al in Europe, and to a lesser
ı other regions are generally
: EEFSU lead to capital out-
:nt account balances toward
ɔital flows to the remaining
e and current accounts shift

Table 1-7. Simulated Effects of European Policies on Real Gross Domestic Product, 2010, 2020, and 2030

Percentage changes from values for business as usual

	EU-Tax			*EU-TaxAdj*		
Country or Group	*2010*	*2020*	*2030*	*2010*	*2020*	*2030*
United States	0.0	0.0	0.0	0.0	0.0	0.0
Japan	0.0	0.0	0.0	0.0	0.0	0.0
Australia	0.0	0.0	0.0	0.0	0.0	0.0
Europe	–0.7	–0.6	–0.7	–0.7	–0.6	–0.7
Other OECD members	0.0	0.0	0.0	0.0	0.0	0.0
China	0.0	0.0	0.0	0.0	0.0	0.0
India	0.0	0.0	0.0	0.0	0.0	0.0
Less-developed countries	0.0	0.0	0.0	0.0	0.0	0.0
EEFSU	–0.2	–0.1	–0.1	–0.7	–0.5	–0.5
OPEC	–0.1	–0.1	–0.1	–0.2	–0.2	–0.2

Source: Authors' simulations.
Note. OECD = Organization for Economic Cooperation and Development; EEFSU = Eastern Europe and the former USSR; OPEC = Organization of the Petroleum Exporting Countries.

Table 1-8. Simulated Effects of European Policies on Carbon Emissions, 2010, 2020, and 2030

Millions of metric tons

	EU-Tax			*EU-TaxAdj*		
Country or Group	*2010*	*2020*	*2030*	*2010*	*2020*	*2030*
United States	2	2	2	0	0	0
Japan	0	0	0	0	0	0
Australia	0	0	0	0	0	0
Europe	–53	–72	–98	–49	–66	–91
Other OECD members	0	0	0	0	0	0
China	0	0	0	0	–1	–1
India	0	0	0	0	0	0
Less-developed countries	1	2	2	–1	–1	–1
EEFSU	2	3	5	–18	–24	–32
OPEC	0	0	0	–1	–2	–2
Total	–48	–64	–88	–69	–93	–127

Source: Authors' simulations.
Note: OECD = Organization for Economic Cooperation and Development; EEFSU = Eastern Europe and the former USSR; OPEC = Organization of the Petroleum Exporting Countries.

toward deficit. The euro strengthens slightly relative to the dollar, as shown in table 1-12. Exchange rates in the model are dollars per unit of foreign currency. An appreciation of the euro relative to the dollar, therefore, appears in the table as a percentage increase in the exchange rate for Europe.

The effects of the policies on European prices and domestic output are shown in table 1-13. The carbon tax policy, shown in the top section of the

Table 1-9. Simulated Effects of European Policies on Short-Run Interest Rates, 2010, 2020, and 2030

Percentage point change

	EU-Tax			*EU-TaxAdj*		
Country or Group	*2010*	*2020*	*2030*	*2010*	*2020*	*2030*
United States	−0.01	−0.01	−0.01	−0.01	−0.01	−0.01
Japan	−0.01	−0.01	−0.01	−0.02	−0.01	−0.01
Australia	−0.01	−0.01	−0.01	−0.02	−0.01	−0.01
Europe	−0.04	−0.03	−0.04	−0.05	−0.04	−0.05
Other OECD members	−0.01	−0.01	−0.01	−0.02	−0.01	−0.02
China	−0.02	−0.01	−0.01	−0.02	−0.01	−0.01
India	−0.01	−0.01	−0.01	−0.01	−0.01	−0.01
Less-developed countries	−0.02	−0.01	−0.01	−0.02	−0.01	−0.02
EEFSU	−0.03	−0.01	−0.02	−0.03	−0.02	−0.02
OPEC	−0.01	−0.01	−0.01	−0.01	−0.01	−0.01

Source: Authors' simulations.
Note: OECD = Organization for Economic Cooperation and Development; EEFSU = Eastern Europe and the former USSR; OPEC = Organization of the Petroleum Exporting Countries.

Table 1-10. Simulated Effects of European Policies on Trade Balances, 2010, 2020, and 2030

Billions of dollars

		EU-Tax			*EU-TaxAdj*	
Country or Group	*2010*	*2020*	*2030*	*2010*	*2020*	*2030*
United States	−2.1	−0.6	0.1	−2.1	−0.4	0.6
Japan	−1.0	−0.3	−0.1	−1.2	−0.4	−0.2
Australia	0.0	0.0	0.0	0.0	0.0	0.0
Europe	5.5	1.6	0.4	4.7	1.9	1.4
Other OECD members	−0.1	0.0	0.0	−0.1	0.0	0.1
China	−0.5	−0.2	−0.1	−0.6	−0.2	−0.1
India	−0.2	−0.1	0.0	−0.2	−0.1	−0.1
Less-developed countries	−1.3	−0.2	0.0	−1.2	−0.3	0.0
EEFSU	0.0	0.1	0.0	1.3	0.5	−0.2
OPEC	0.0	0.0	0.1	0.1	0.0	0.1

Source: Authors' simulations.
Note: OECD = Organization for Economic Cooperation and Development; EEFSU = Eastern Europe and the former USSR; OPEC = Organization of the Petroleum Exporting Countries.

table, raises coal prices sharply: by 23 percent in 2010, rising to 33 percent in 2030. Coal output drops by 8 percent in 2010, rising to 13 percent in 2030. Other energy prices, including the natural gas price, rise as well, although by much smaller percentages: 5 to 6 percent for crude oil and refined petroleum, and 1 to 2 percent for electricity. The combined tax and BTA policy shown in the bottom of the table is very similar, but with slightly larger increases in most prices (due to the tariffs) and slightly smaller reductions in output (due to the

Table 1-11. Simulated Effects of European Policies on Current Accounts, 2010, 2020, and 2030

Billions of dollars

	EU-Tax			*EU-TaxAdj*		
Country or Group	*2010*	*2020*	*2030*	*2010*	*2020*	*2030*
United States	−3.0	−2.7	−3.4	−3.1	−2.9	−3.7
Japan	−1.6	−1.3	−1.7	−1.9	−1.7	−2.2
Australia	0.0	0.0	0.0	0.0	0.0	0.0
Europe	7.9	6.7	8.6	6.5	6.1	8.5
Other OECD members	−0.3	−0.3	−0.3	−0.3	−0.2	−0.3
China	−0.7	−0.6	−0.7	−0.9	−0.7	−1.0
India	−0.2	−0.2	−0.3	−0.3	−0.3	−0.4
Less-developed countries	−1.9	−1.4	−1.7	−1.7	−1.4	−1.8
EEFSU	0.0	0.2	0.1	1.9	1.9	2.0
OPEC	−0.1	−0.1	−0.1	0.1	0.1	0.0

Source: Authors' simulations.

Note: OECD = Organization for Economic Cooperation and Development; EEFSU = Eastern Europe and the former USSR; OPEC = Organization of the Petroleum Exporting Countries.

Table 1-12. Simulated Effects of European Policies on Real Exchange Rates, 2010, 2020, and 2030

Percentage changes from values for business as usual

	EU-Tax			*EU-TaxAdj*		
Country or Group	*2010*	*2020*	*2030*	*2010*	*2020*	*2030*
United States	—	—	—	—	—	—
Japan	−0.1	−0.1	−0.1	−0.1	0.0	0.0
Australia	−0.1	−0.1	−0.1	−0.1	−0.1	−0.1
Europe	0.5	0.7	1.0	0.9	1.2	1.5
Other OECD members	0.0	0.0	0.0	0.0	0.0	0.1
China	−0.1	−0.1	0.0	−0.1	−0.1	0.0
India	0.0	0.0	0.0	0.0	0.0	0.0
Less-developed countries	−0.1	0.0	0.0	−0.1	−0.1	0.0
EEFSU	−0.3	−0.2	−0.1	−0.9	−0.8	−0.7
OPEC	−0.2	−0.2	−0.2	−0.3	−0.3	−0.3

Source: Authors' simulations.

Note: Exchange rates are measured as dollars per unit of foreign currency. OECD = Organization for Economic Cooperation and Development; EEFSU = Eastern Europe and the former USSR; OPEC = Organization of the Petroleum Exporting Countries.

shift away from imports to domestic production). However, the protective effect of the adjustments for European producers is very small, typically raising output by only 0.1 percent relative to the carbon tax alone.

Tables 1-14 through 1-20 show the effects of the two U.S. policies on the same set of variables. In general, the effects of the carbon tax are similar in magnitude but with the United States and the region representing other OECD members (which includes Canada and Mexico) filling the roles of Europe and

Table 1-13. Simulated Effects of European Policies on European Prices and Output, 2010, 2020, and 2030

Percentage changes from values for business as usual

	Prices			*Quantities*		
Sector	*2010*	*2020*	*2030*	*2010*	*2020*	*2030*
EU-Tax						
Electric utilities	1.6	1.9	2.2	−1.0	−1.1	−1.3
Gas utilities	0.5	0.4	0.5	−1.3	−1.6	−1.9
Petroleum refining	4.5	5.1	6.1	−2.8	−3.0	−3.4
Coal	22.5	27.8	33.4	−7.5	−9.8	−13.1
Crude oil	4.9	5.6	6.7	−3.3	−4.0	−5.1
Mining	0.5	0.4	0.5	−1.0	−0.8	−0.9
Agriculture	0.4	0.3	0.4	−0.1	−0.1	−0.2
Forestry and wood products	0.3	0.2	0.2	−0.5	−0.4	−0.4
Durables	0.3	0.1	0.2	−1.1	−0.6	−0.7
Nondurables	0.4	0.4	0.4	−0.2	−0.1	−0.2
Transportation	0.5	0.5	0.6	−0.4	−0.4	−0.4
Services	0.3	0.2	0.2	0.0	0.1	0.1
EU-TaxAdj						
Electric utilities	1.6	1.9	2.2	−0.9	−1.0	−1.2
Gas utilities	0.5	0.4	0.5	−1.3	−1.6	−1.9
Petroleum refining	4.8	5.6	6.6	−2.4	−2.6	−3.0
Coal	22.3	27.5	33.1	−7.5	−9.8	−13.0
Crude oil	4.8	5.5	6.5	−3.1	−3.7	−4.8
Mining	0.5	0.5	0.6	−1.2	−0.9	−1.0
Agriculture	0.3	0.3	0.3	−0.2	−0.2	−0.2
Forestry and wood products	0.2	0.1	0.1	−0.5	−0.4	−0.4
Durables	0.2	0.1	0.1	−1.2	−0.7	−0.8
Nondurables	0.4	0.4	0.4	−0.2	−0.2	−0.2
Transportation	0.5	0.5	0.6	−0.5	−0.4	−0.5
Services	0.2	0.1	0.2	0.1	0.2	0.2

Source: Authors' simulations.

the EEFSU. Table 1-14 shows that the carbon tax reduces U.S. GDP by 0.6 to 0.7 percent and other OECD members' GDP by 0.3 to 0.4 percent. Adding BTAs has negligible effect on U.S. GDP but increases the effect on other OECD members' GDP to reductions of 0.8 to 0.1 percent. Also, additional regions are affected as well, particularly developing countries.

As shown in table 1-15, the carbon tax reduces U.S. carbon emissions by much more than it reduced European emissions: 303 to 577 mmt per year over the period 2010–30. As with the European case, the carbon tax alone leads to some leakage of emissions: World emissions fall by 293 to 554 mmt. Leakage, therefore, ranges from 10 to 23 mmt, or 3 to 4 percent of the U.S. reduction.

opean Prices and Output,

	Quantities	
2010	2020	2030
−1.0	−1.1	−1.3
−1.3	−1.6	−1.9
−2.8	−3.0	−3.4
−7.5	−9.8	−13.1
−3.3	−4.0	−5.1
−1.0	−0.8	−0.9
−0.1	−0.1	−0.2
−0.5	−0.4	−0.4
−1.1	−0.6	−0.7
−0.2	−0.1	−0.2
−0.4	−0.4	−0.4
0.0	0.1	0.1
−0.9	−1.0	−1.2
−1.3	−1.6	−1.9
−2.4	−2.6	−3.0
−7.5	−9.8	−13.0
−3.1	−3.7	−4.8
−1.2	−0.9	−1.0
−0.2	−0.2	−0.2
−0.5	−0.4	−0.4
−1.2	−0.7	−0.8
−0.2	−0.2	−0.2
−0.5	−0.4	−0.5
0.1	0.2	0.2

luces U.S. GDP by 0.6 to
).4 percent. Adding BTAs
ect on other OECD mem-
), additional regions are

I.S. carbon emissions by
to 577 mmt per year over
carbon tax alone leads to
93 to 554 mmt. Leakage,
nt of the U.S. reduction.

Table 1-14. Simulated Effects of U.S. Policies on Real Gross Domestic Product, 2010, 2020, and 2030

Percentage changes from values for business as usual

	US-Tax			US-TaxAdj		
Country or Group	*2010*	*2020*	*2030*	*2010*	*2020*	*2030*
United States	−0.6	−0.6	−0.7	−0.6	−0.6	−0.7
Japan	0.0	0.0	0.0	−0.1	−0.1	−0.1
Australia	0.0	0.0	0.0	−0.1	−0.1	0.0
Europe	0.0	0.0	0.0	−0.1	−0.1	−0.1
Other OECD members	−0.4	−0.3	−0.3	−1.0	−0.8	−0.8
China	0.0	0.0	0.0	0.0	0.0	0.0
India	0.0	0.0	0.0	−0.1	−0.1	−0.1
Less-developed countries	−0.2	−0.1	−0.1	−0.5	−0.2	−0.2
EEFSU	0.0	0.0	0.0	−0.1	−0.1	−0.1
OPEC	−0.4	−0.3	−0.3	−0.5	−0.4	−0.3

Source: Authors' simulations.
Note: Exchange rates are measured as dollars per unit of foreign currency. OECD = Organization for Economic Cooperation and Development; EEFSU = Eastern Europe and the former USSR; OPEC = Organization of the Petroleum Exporting Countries.

Table 1-15. Simulated Effects of U.S. Policies on Carbon Emissions, 2010, 2020, and 2030

Millions of metric tons

	US-Tax			US-TaxAdj		
Country or Group	*2010*	*2020*	*2030*	*2010*	*2020*	*2030*
United States	−303	−422	−577	−279	−390	−535
Japan	0	0	0	−1	−1	−1
Australia	0	0	0	0	0	0
Europe	1	2	2	−2	−3	−3
Other OECD members	3	4	6	−4	−5	−6
China	0	0	0	−1	−2	−2
India	0	0	0	−1	−1	−1
Less-developed countries	5	8	11	−6	−4	−5
EEFSU	1	1	2	−2	−2	−2
OPEC	0	0	1	−1	−1	−2
Total	−293	−405	−554	−297	−407	−558

Source: Authors' simulations.
Note: Exchange rates are measured as dollars per unit of foreign currency. OECD = Organization for Economic Cooperation and Development; EEFSU = Eastern Europe and the former USSR; OPEC = Organization of the Petroleum Exporting Countries.

As with the European simulations, adding BTAs causes the U.S. reduction to be smaller but causes larger drops in emissions outside the United States and results in slightly larger global reductions: 297 to 558 mmt annually over the period 2010–30.

The effects on short-run interest rates are shown in table 1-16, and the main effect is a small reduction in rates in the United States. Under the carbon tax,

Table 1-16. Simulated Effects of U.S. Policies on Short-Run Interest Rates, 2010, 2020, and 2030

Percentage point change

	US-Tax			*US-TaxAdj*		
Country or Group	*2010*	*2020*	*2030*	*2010*	*2020*	*2030*
United States	−0.02	−0.03	−0.03	−0.05	−0.04	−0.04
Japan	−0.01	0.00	0.00	−0.01	0.01	0.01
Australia	−0.02	−0.01	−0.01	−0.03	−0.01	−0.01
Europe	−0.01	0.00	0.00	−0.02	0.00	0.00
Other OECD members	−0.01	0.00	0.00	0.03	0.00	0.00
China	−0.01	0.00	0.00	0.00	0.01	0.01
India	0.00	0.00	0.00	0.01	0.01	0.01
Less-developed countries	−0.01	0.00	0.00	0.01	0.01	0.01
EEFSU	−0.01	0.00	0.00	−0.01	0.00	0.00
OPEC	0.01	0.01	0.01	0.02	0.01	0.01

Source: Authors' simulations.

Note: Exchange rates are measured as dollars per unit of foreign currency. OECD = Organization for Economic Cooperation and Development; EEFSU = Eastern Europe and the former USSR; OPEC = Organization of the Petroleum Exporting Countries.

Table 1-17. Simulated Effects of U.S. Policies on Trade Balances, 2010, 2020, and 2030

Billions of dollars

	US-Tax			*US-TaxAdj*		
Country or Group	*2010*	*2020*	*2030*	*2010*	*2020*	*2030*
United States	−0.5	−0.9	0.4	−4.6	−1.2	4.3
Japan	−0.2	0.7	0.9	0.4	1.6	1.6
Australia	0.2	0.2	0.1	0.6	0.4	0.3
Europe	−1.0	−0.4	−0.8	0.5	−0.5	−2.7
Other OECD members	1.2	0.9	0.5	2.9	1.9	1.0
China	−0.4	0.0	0.0	−0.8	0.0	−0.3
India	0.0	0.1	0.2	0.1	0.3	0.3
Less-developed countries	0.3	−0.1	−0.4	1.4	−0.8	−1.6
EEFSU	0.4	0.5	0.5	1.0	1.1	1.0
OPEC	0.5	−0.3	−0.7	−0.1	−1.0	−1.5

Source: Authors' simulations.

Note: Exchange rates are measured as dollars per unit of foreign currency. OECD = Organization for Economic Cooperation and Development; EEFSU = Eastern Europe and the former USSR; OPEC = Organization of the Petroleum Exporting Countries.

the result is a small capital outflow, as reflected in the shift of the current account toward surplus in table 1-18. Interestingly, the capital flow reverses under the BTA policy. When the United States increases its tariffs, the reduction in trade reduces GDP in many regions (table 1-14) and leaves the U.S. economy in a relatively stronger position. The dollar strengthens in both simulations, as shown in table 1-19.

Table 1-18. Simulated Effects of U.S. Policies on Current Accounts, 2010, 2020, and 2030

Billions of dollars

	US-Tax			*US-TaxAdj*		
Country or Group	*2010*	*2020*	*2030*	*2010*	*2020*	*2030*
United States	0.8	0.2	1.8	–5.1	–4.2	0.0
Japan	–1.4	–1.0	–1.5	–1.7	–1.4	–2.6
Australia	0.3	0.4	0.5	0.8	0.9	1.1
Europe	–2.1	–1.6	–2.4	–0.3	–0.5	–2.1
Other OECD members	1.4	1.6	1.7	3.5	3.6	4.0
China	–0.6	–0.2	–0.4	–0.9	–0.2	–0.7
India	0.0	0.1	0.1	0.2	0.3	0.3
Less-developed countries	0.5	0.4	0.4	3.0	1.7	1.9
EEFSU	0.4	0.5	0.7	1.2	1.5	1.7
OPEC	0.8	0.4	0.4	0.3	–0.3	–0.4

Source: Authors' simulations.

Note: Exchange rates are measured as dollars per unit of foreign currency. OECD = Organization for Economic Cooperation and Development; EEFSU = Eastern Europe and the former USSR; OPEC = Organization of the Petroleum Exporting Countries.

Table 1-19. Simulated Effects of U.S. Policies on Real Exchange Rates, 2010, 2020, and 2030

Percentage changes from values for business as usual

	US-Tax			*US-TaxAdj*		
Country or Group	*2010*	*2020*	*2030*	*2010*	*2020*	*2030*
United States	—	—	—	—	—	—
Japan	–2.0	–2.1	–2.4	–4.6	–5.0	–5.6
Australia	–1.7	–1.8	–2.0	–3.9	–4.1	–4.4
Europe	–1.8	–1.9	–2.2	–4.2	–4.5	–5.0
Other OECD members	–2.2	–2.4	–2.6	–5.0	–5.4	–5.9
China	–1.8	–1.9	–2.2	–4.1	–4.5	–5.0
India	–1.8	–2.0	–2.3	–4.3	–4.7	–5.2
Less-developed countries	–1.8	–2.0	–2.3	–4.2	–4.7	–5.2
EEFSU	–1.8	–1.9	–2.2	–4.1	–4.4	–4.8
OPEC	–2.2	–2.5	–2.8	–4.1	–4.7	–5.2

Source: Authors' simulations.

Note: Exchange rates are measured as dollars per unit of foreign currency. OECD = Organization for Economic Cooperation and Development; EEFSU = Eastern Europe and the former USSR; OPEC = Organization of the Petroleum Exporting Countries.

As shown in table 1-20, the U.S. carbon tax causes much larger percentage changes in fuel prices than did the European tax, reflecting the lower initial energy prices in the United States. The price of coal rises by 50 to 94 percent, compared with the 23 to 33 percent increase under the European policy. Fuel consumption, in turn, falls by larger percentages; coal, for example, drops by 20 to 29 percent rather than the 8 to 13 percent in Europe. It is interesting to

Table 1-20. Simulated Effects of U.S. Policies on U.S. Prices and Output, 2010, 2020, and 2030

Percentage changes from values for business as usual

	Prices			*Quantities*		
Sector	*2010*	*2020*	*2030*	*2010*	*2020*	*2030*
US-Tax						
Electric utilities	6.6	7.9	9.4	−3.6	−4.3	−5.0
Gas utilities	1.1	1.2	1.4	−3.7	−4.4	−5.3
Petroleum refining	14.3	17.2	20.6	−10.9	−12.4	−13.8
Coal	59.7	75.9	94.3	−19.4	−23.7	−28.3
Crude oil	18.6	22.6	27.2	−13.2	−15.3	−19.0
Mining	0.6	0.6	0.7	−1.0	−0.8	−0.8
Agriculture	0.3	0.4	0.4	−0.3	−0.3	−0.4
Forestry and wood products	0.0	−0.1	0.0	−0.4	−0.2	−0.3
Durables	−0.1	−0.2	−0.2	−0.7	−0.4	−0.4
Nondurables	0.3	0.4	0.5	−0.2	−0.2	−0.3
Transportation	0.5	0.5	0.6	−0.4	−0.3	−0.4
Services	0.2	0.2	0.2	0.1	0.1	0.1
US-TaxAdj						
Electric utilities	6.6	8.0	9.5	−3.5	−4.2	−4.9
Gas utilities	1.1	1.1	1.3	−3.7	−4.4	−5.2
Petroleum refining	14.9	18.2	22.0	−9.1	−10.4	−11.7
Coal	59.5	75.8	94.2	−19.5	−23.9	−28.5
Crude oil	17.0	20.8	25.2	−13.3	−15.3	−18.9
Mining	0.5	0.5	0.7	−1.6	−1.4	−1.4
Agriculture	0.1	0.2	0.3	−0.6	−0.6	−0.7
Forestry and wood products	−0.3	−0.3	−0.3	−0.2	0.0	−0.1
Durables	−0.1	−0.1	0.0	−1.1	−0.7	−0.8
Nondurables	0.3	0.3	0.5	−0.3	−0.3	−0.4
Transportation	0.5	0.5	0.6	−0.3	−0.3	−0.4
Services	0.2	0.1	0.2	0.2	0.2	0.2

Source: Authors' simulations.

note that the BTAs generally do not have the mild protective effect seen under the European case. The reduction in world GDP, and the consequent drop in demand for U.S. exports, more than offsets the shift of domestic consumption from imports to domestic producers.

Conclusion

Carbon taxes on trade in primary energy commodities (that is, coal, oil, natural gas) are straightforward and would likely be part of any domestic carbon tax or permit trading system. Computing BTAs for the carbon content of all other traded goods and services, however, is very complex. In practice, it would

; and Output, 2010, 2020,

Quantities		
2010	2020	2030
−3.6	−4.3	−5.0
−3.7	−4.4	−5.3
−10.9	−12.4	−13.8
−19.4	−23.7	−28.3
−13.2	−15.3	−19.0
−1.0	−0.8	−0.8
−0.3	−0.3	−0.4
−0.4	−0.2	−0.3
−0.7	−0.4	−0.4
−0.2	−0.2	−0.3
−0.4	−0.3	−0.4
0.1	0.1	0.1
−3.5	−4.2	−4.9
−3.7	−4.4	−5.2
−9.1	−10.4	−11.7
−19.5	−23.9	−28.5
−13.3	−15.3	−18.9
−1.6	−1.4	−1.4
−0.6	−0.6	−0.7
−0.2	0.0	−0.1
−1.1	−0.7	−0.8
−0.3	−0.3	−0.4
−0.3	−0.3	−0.4
0.2	0.2	0.2

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require calculations on a country-of-origin basis for all trading partners of the country applying the BTAs. The complexities increase when a good that has been manufactured contains intermediate goods that have a number of different sources across countries. However, our results show that the tariffs would be small for most goods at moderate carbon tax levels. At an aggregate level, the adjustments for most manufactured goods would be on the order of 1 or 2 percent. However, within some narrowly defined and energy-intensive industries, such as aluminum refining, the rates would be considerably higher. Also, the adjustments are proportional to the carbon tax being imposed, so very high carbon taxes could lead to more significant BTAs.

We find that the BTAs would be effective at reducing leakage of emissions, but leakage is very small even without the BTAs. Moreover, much of the emissions gain that does occur comes about because the tariffs reduce world GDP through the overall reduction in international trade. Finally, because the BTAs are small, they have little effect on import-competing industries. We conclude that the benefits produced by BTAs for traded goods and services would be small, and they are unlikely to justify their administrative complexity or their deleterious effects on international trade.

Comments

Comment by Nils Axel Braathen

Any nonglobal policy to combat climate change would lead to some "leakage" of emissions to countries that do not participate in the "carbon coalition"—and demands for protection of the competitiveness of the most vulnerable economic sectors are to be expected. This leakage can occur through three main channels:

—via losses in competitiveness of certain sectors;

—via the markets for fossil fuels—because a reduction in fuel demand in the coalition would lead to lower world-market fuel prices and increased fuel demand in other countries;

—via changes in foreign direct investments.

The Organization for Economic Cooperation and Development (OECD) published studies of the effects of carbon taxes and border tax adjustments (BTAs) in the steel and cement sectors a few years ago—based on simulations with partial equilibrium models.[1] These simulations indicated that a nonglobal carbon tax could have a clear negative impact on the competitiveness of these sectors within the coalition—and that, in principle, BTAs could significantly reduce these effects.

For example, the steel sector study illustrated the effects of an OECD-wide tax of $25 per metric ton of carbon dioxide (CO_2). In this context, it was found that if both import taxes and export subsidies were implemented and were differentiated across steel types, and if the border tax rates were linked to emission levels in non-OECD countries, the decline in OECD steel production might be as small as 1 percent—as opposed to 9 percent if no adjustments were made. At the same time, the reduction in global emissions (5.1 percent) would be larger than without BTAs (4.6 percent). This is because the border taxes keep

1. For steel, see OECD (2003). For cement, see OECD (2005).

a higher share of world steel production within the OECD area, thus making more steel producers subject to the OECD-wide carbon tax.

Given their partial nature, these simulations only capture the first of the three sources of leakage listed above. Ongoing simulations with a general equilibrium model (called ENV-Linkages) at the OECD also capture the second source of leakage—and these simulations indicate that the effects via the fossil fuel markets under certain conditions are much more important than the sectoral competitiveness effects.[2,3]

However, the relative magnitude of fossil fuel market effects and sectoral competitiveness effects on total leakage seems to depend on the size of the carbon coalition. If the coalition is "large"—say, comprising all the Annex I countries—global fossil fuel demand would be reduced to a significant extent, which would trigger a significant reduction in world market fuel prices (especially for oil). This would in turn lead to a relatively strong increase in the demand for these fuels in countries outside the coalition—making this source of leakage dwarf the leakage effects stemming from a loss of sectoral competitiveness. In such a situation, BTAs would affect total carbon leakage only to a limited extent—in line with the findings of McKibbin and Wilcoxen.

If, conversely, the size of the carbon coalition is much smaller—say, only comprising the EU countries—the effects on global fossil fuel demand would be much smaller, leading to less leakage through this channel. Total leakage in this case would, however, be larger than in the previous case, due to more important sectoral competitiveness effects. In such a situation, the environmental arguments for applying BTAs could be somewhat stronger—with some important caveats, mentioned below.

While McKibbin and Wilcoxen's G-Cubed model covers only CO_2 emissions, the ENV-Linkages model also include other greenhouse gases, and the this seem to be of some importance. As long as not all relatively low-cost abatement options related to non-CO_2 greenhouse gases have been exhausted, total leakage tends to be lower when these gases are included in the analysis—as the effects are shifted from the fossil fuel markets, hence reducing the leakages that are generated through this channel, to other sectors, in particular agriculture.

It should, however, be kept in mind that the distortions created by BTAs would represent a significant economic cost—even when disregarding the very important administrative costs they would entail. As indicated by McKibbin

2. OECD (2008) provides further information about these simulations.

3. As opposed to the ENV-Linkages model, the model used by McKibbin and Wilcoxen, G-Cubed, also captures carbon leakages that stem from changes in foreign direct investment. Unfortunately, the chapter does not indicate the relative magnitude of these effects.

and Wilcoxen, to be as effective as possible, the BTAs on imports ought to be based on the carbon content of relevant products in the country where they are produced—which obviously would be very difficult to monitor and enforce in practice.

Further, the compatibility of carbon-policy-based BTAs with World Trade Organization (WTO) rules remains an open question. An overview of this issue in a recent OECD book concluded that only a WTO panel could resolve the question of the legality of such measures.[4]

Regardless of the legality of any BTA measures under the WTO, there is an important danger that the introduction of such measures could trigger tit-for-tat retaliations from the countries that would be "hit" by these measures. This could in turn have serious effects on world trade and economic development.

Hence—in line with McKibbin and Wilcoxen's conclusions—BTAs should only be considered as a last resort. The focus should instead be firmly fixed on *achieving an ambitious international approach* to address the climate change problem, with *participation by all the major greenhouse-gas-emitting countries and sectors.*

Comment by (Tom) Hu Tao

In chapter 1, McKibbin and Wilcoxen quantify the significant differences in carbon efficiency between the United States and China and India. In so doing, they provide useful analytical insights. I would like to share several comments on the issue of proposals embodied in bills like Lieberman-Warner to impose import tariffs based on the carbon content of goods.

First, when addressing the U.S. desire to impose import tariffs based on the carbon content of goods (as proposed in Lieberman-Warner-type bills) the United States' history with the Kyoto Protocol is relevant. So far, the United States is the only Annex I country that has not signed the protocol. By contrast, China and India have signed the protocol, although, because they are non–Annex I countries, they do not have legally binding obligations for greenhouse gas reductions. The post-protocol negotiation is still under way following the Bali Road Map, and there are as yet no new agreements. Given that the United States has not signed the protocol and that China and India have, it is not clear how the United States' proposed "punishment" of these countries is consistent with international agreements like the United Nations Framework Convention on Climate Change and the protocol.

4. OECD (2006, chapter 5).

Second, the Lieberman-Warner Bill and other similar bills ignore China's own domestic policies. On January 1, 2007, China implemented export tariffs ranging from 5 to 25 percent on carbon-, pollution-, and resource-intensive products, including iron, steel, coke, cement, and so on. Thus, China has already internalized the environmental costs in the prices of these products before exporting them. The tariff rate that China has applied is higher than the rate proposed in legislation. Therefore, it is unclear why the United States needs to implement a border tax adjustment (BTA) to internalize the environmental costs from China. In fact, if the United States were to implement such a bill, it would amount to the double taxation of the environmental externality for U.S. users of such products.

Third, though this proposed legislation is addressing U.S. competitiveness worries stemming from stronger environmental protection, China may also have competitiveness worries. U.S. products are not always more energy-efficient than Chinese products. More and more Chinese products have higher energy-efficiency standards than U.S. products. For example, China has adopted Euro IV vehicle emission standards, which are more stringent than both U.S. and California emission standards. Since China started the China Energy Efficiency Program two years ago, it has implemented more stringent energy standards than the United States for such products as refrigerators, air conditioners, washers, and other electric and electronic appliances. By the same logic that the United States is looking at BTAs, China could seek BTAs on the products mentioned above. Additionally, if BTAs come into vogue, China and India might view subsidized U.S. agricultural products as meriting BTAs on competitiveness grounds.

Fourth, this type of legislation is inconsistent with other aspects of U.S. policy. The Office of the United States Trade Representative (USTR), in a report submitted to Congress on China's implementation of World Trade Organization (WTO) commitments in December 2007, accused China of violating WTO rules on twelve products, including some high-carbon-content products, like coke for iron and steel. Later, the USTR warned China that it would bring a case at the WTO if China did not abolish export limits for these twelve products. The proposed legislation trying to reduce exports of high-carbon-content products from China is inconsistent with the USTR's attempts to increase exports of certain high-carbon-content products.

Comment by Arik Levinson

McKibbin and Wilcoxen's analysis in chapter 1 of this volume is prospective. It predicts future trade patterns after developed countries unilaterally impose hypothetical carbon taxes that disproportionately affect carbon-intensive industries. Their analysis is sophisticated, state of the art, and probably the best conceivable approximation of the true future effect of carbon taxes on trade, but it remains in the end a forecast—arguably not something at which economists excel.

My point, then, is that we can learn about the significance of the carbon content of trade by a *retrospective* analysis, so long as we are willing to replace as-yet-unregulated carbon for a pollutant developed countries began regulating thirty years ago. The idea is that it is easier to say what happened thirty years ago than to predict what will happen thirty years from now.

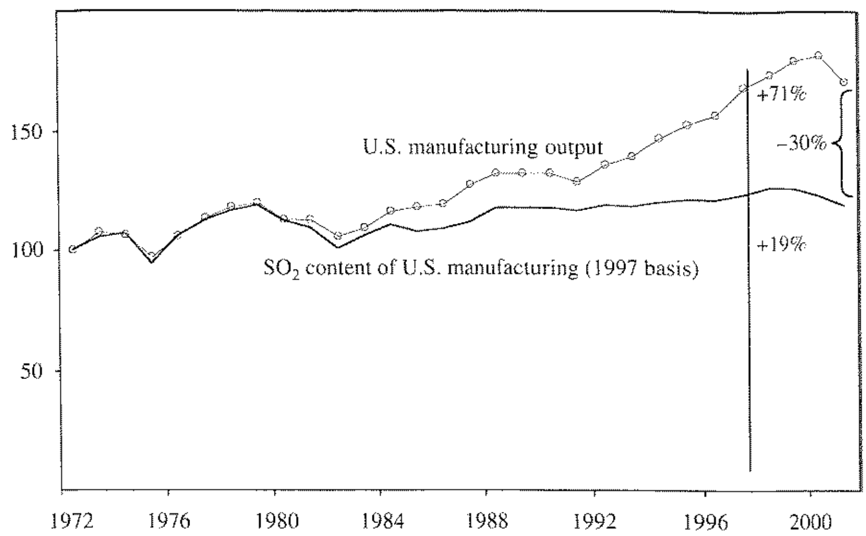
Thirty years ago, the United States unilaterally imposed strict pollution regulations that disproportionately affected pollution-intensive industries, raising fears that those industries would relocate to "pollution havens," a process now being called "leakage." Pollution-abatement operating costs for the manufacturing sector in the United States doubled as a fraction of value shipped between 1974 and 1991, but this doubling was spread unevenly across industries. For some industries (petroleum refining, primary metals, pulp and paper), costs tripled or even quadrupled. For others, pollution-abatement costs remained small or even declined. Did this change in comparative advantage across manufacturing industries lead to leakage in the past? For the evidence of that, it is useful to begin with U.S. manufacturing output for 1972 to 2001, depicted in figure 1C-1.

The top line in figure 1C-1 plots the real value shipped by U.S. manufacturers, from 1972 to 2001, indexed so the 1972 value equals 100. Real manufacturing output rose 71 percent. If over this period there were no change in the technology of abatement or production, and no change in the mix of industries making up U.S. manufacturing, then we would expect pollution emitted by U.S. manufacturers to also have risen 71 percent over this period. (Manufacturers would be producing 71 percent more of the same goods using the same methods.) But of course we know that the composition of U.S. manufacturing output has changed. America produces different goods today than it did thirty years ago—and one of the reasons might be "leakage" caused by polluting industries avoiding U.S. environmental regulations.

The bottom line in figure 1C-1 calculates the extent of the change in the composition of U.S. industries as it affects one particular pollutant, sulfur dioxide (SO_2). It uses the 1997 emissions intensities of each of the 470 industries

Figure 1C-1. The Sulfur Dioxide Content of U.S. Manufacturing, 1972–2001

Index: 1972 = 100



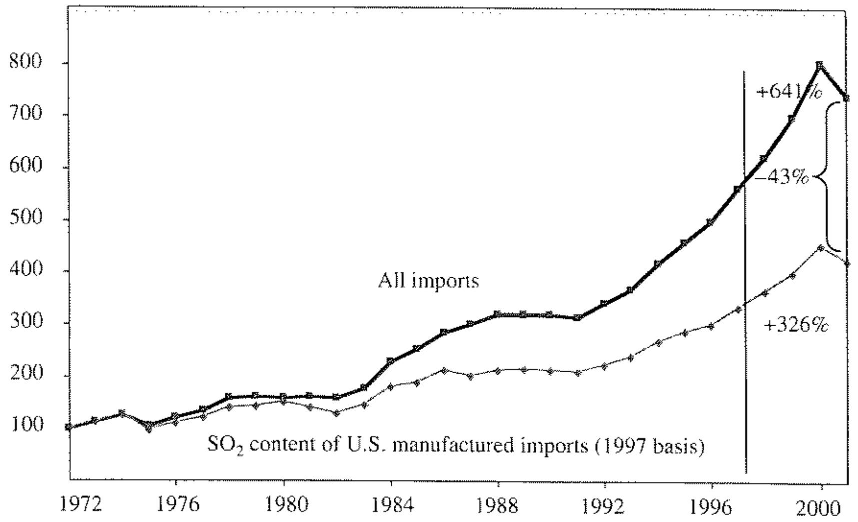
Source: Author's calculations based on NBER-CES Manufacturing Productivity Database, and EPA Trade and Environmental Assessment Model (TEAM).

that make up the manufacturing sector, as calculated by the U.S. Environmental Protection Agency. For every year, I multiplied each industry's output by its corresponding 1997 emissions intensity, and then summed the predicted SO_2 emissions across all industries. The result is the predicted amount of SO_2 that would have been emitted by U.S. manufacturing, using the 1997 technologies but the concurrent scale and mix of industries. The bottom line rises 19 percent and is lower than the 71 percent manufacturing growth for one reason: U.S. manufacturing shifted toward industries that emit less SO_2. This "green shift" of U.S. manufacturing composition resulted in SO_2 emissions that were 30 percent lower than they would have been had the mix of industries remained the same. Where did this extra SO_2 pollution go? If the SO_2-intensive industries fled to pollution havens and imported their products to the United States, we would call that leakage.

To examine whether the green shift of U.S. manufacturing might be explained by leakage, figure 1C-2 conducts exactly the same analysis but with imported manufactured goods instead of domestically produced goods. Here I am careful to account for the pollution caused by intermediate inputs to the final imports, using a Leontief-style input/output calculation similar to that used by McKibbin and Wilcoxen. The top line in figure 1C-2 depicts the real value of

Figure 1C-2. The Sulfur Dioxide Content of U.S. Imports, 1972–2001

Index: 1972 = 100



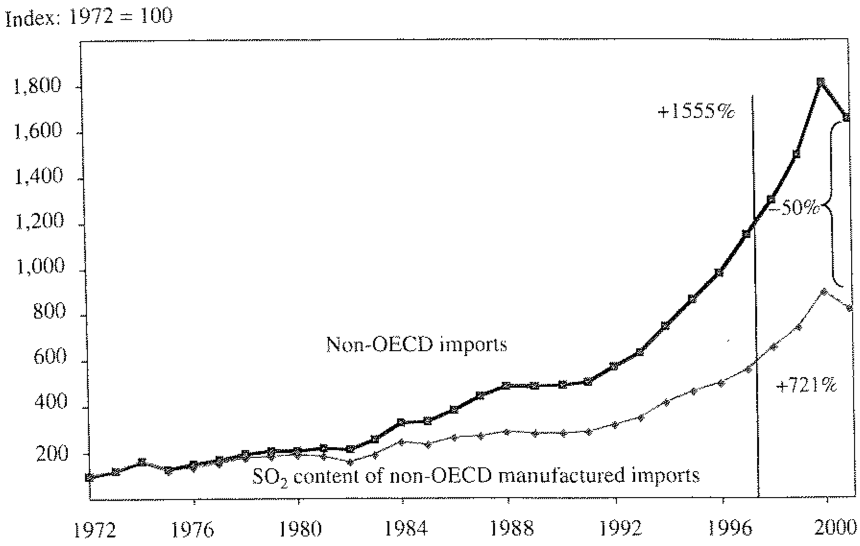
Source: Author's calculations based on NBER-CES Manufacturing Productivity Database, Center for International Data (www.internationaldata.org), and Bureau of Economic Analysis 1997 Input-Output Tables.

imports, which increased 641 percent from 1972 to 2001. The bottom line depicts the SO_2 that would have been emitted as a consequence of manufacturing those imports, had they been produced in the United States using 1997 technologies.

Figure 1C-2 depicts two noteworthy results. First, the composition of imports became cleaner over time, not dirtier. The 30 percent green shift of U.S. manufacturing was not accompanied by a corresponding "brown shift" on the part of imported goods. Instead, the composition of imports also shifted toward less-pollution-intensive goods. Second, and perhaps more startling, imports shifted toward less-polluting goods *faster* than domestic goods. The SO_2 content of imported goods was 43 percent lower that it would have been if the mix of goods being imported had remained constant.

Now, some might look at figure 1C-2 and note that U.S. imports are dominated by trade with other developed economies that were themselves enacting strict environmental regulations during this period: Canada, Japan, and the European nations. If there was leakage, perhaps the SO_2 moved to developing countries that were more likely to be pollution havens. That shift might not be

Figure 1C-3. The Sulfur Dioxide Content of U.S. Imports from Countries That Are Not Members of the Organization for Economic Cooperation and Development (OECD), 1972–2001



Source: Author's calculations based on NBER-CES Manufacturing Productivity Database, Center for International Data (www.internationaldata.org), and Bureau of Economic Analysis 1997 Input-Output Tables.

apparent in aggregate import data, which were composed mostly of imports from developed economies.

To address that concern, figure 1C-3 conducts exactly the same analysis but limited to imports from countries that are not members of the Organization for Economic Cooperation and Development (OECD). The figure rebuts the conjecture that leakage will be apparent in import data from less-developed countries. In fact, the green shift in imports from non-OECD countries (50 percent) was even larger than the green shift in aggregate imports (43 percent), which was itself larger than the green shift in domestic production (30 percent).

Thirty years ago, the United States began seriously regulating industrial emissions of common air pollutants such as SO_2. In the ensuing years, the U.S. manufacturing base has shifted away from production of goods that emit SO_2. But at the same time, imports to the United States, in general and from non-OECD countries in particular, have also shifted away from SO_2-intensive goods.

Note that these trends do not mean that there was no leakage of SO_2 emissions from the United States to importing countries. It could be that there was leakage, and as a consequence, the U.S. manufacturing green shift was larger than it otherwise would have been, and the imported goods' green shift was smaller. To assess that possibility, we need a general equilibrium analysis like that of McKibbin and Wilcoxen. All this analysis shows is that if there was leakage, it is not apparent in aggregate data and was swamped by other changes in the past thirty years: trade liberalization, oil prices, labor costs, and changing preferences. My forecast, then, based on this retrospective analysis, is that any carbon leakage in the future will also be swamped by as-yet-unforeseen forces affecting the composition of trade.

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