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Frameworks for Evaluating Policy Approaches to Address the Competitiveness Concerns of Mitigating Greenhouse Gas Emissions

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**FRAMEWORKS FOR EVALUATING POLICY APPROACHES TO ADDRESS THE
COMPETITIVENESS CONCERNS OF MITIGATING GREENHOUSE GAS EMISSIONS**

Joseph E. Aldy
June 23, 2016 Draft

Domestic carbon pricing policies may impose adverse competitiveness risks on energy-intensive firms competing with foreign firms that may bear a lower carbon price. The risks of competitiveness effects include adverse economic and environmental outcomes, which can undermine political support for carbon pricing. Competitiveness policies, such as border tax adjustments, output-based tax credits, and related policies, also carry potential risks: unfavorable distributional outcomes, less cost-effective, and harming international trade and climate negotiations. This paper reviews the theoretical and empirical research on competitiveness risks, and the risks posed by competitiveness policies, and presents two alternative frameworks for evaluating competitiveness policy options.

Keywords: border tax, tariffs, leakage, competitiveness, political economy

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I. INTRODUCTION

Most public policies intended to mitigate greenhouse gas emissions impose economic costs. Requiring automobile manufacturers to improve the fuel economy of the cars they sell increases the costs of making new cars and translates into higher prices faced by consumers. Mandating utilities to lower the carbon intensity of their power generation will cause them to shift investment into higher-cost generating technologies, which in turn will result in higher electricity rates. Setting a price on carbon for fossil fuels throughout the economy will raise energy prices.

The costs of these climate policies may negatively affect domestic firms if their competitors do not face comparable emissions regulation or taxation. In particular, energy-intensive manufacturing industries have expressed concerns that domestic climate change policy could impose adverse competitiveness effects because it would raise their production costs relative to those of their foreign competitors. To be more exact, the competitiveness effect reflects the impacts of the differential in carbon prices or the effective gap in the shadow price of carbon between two domestic climate programs on those countries' net imports. Thus firms operating under the higher carbon price experience adverse competitiveness effects if their domestic or foreign market share declines. This could result in lower production, job loss, and relocation of factories to countries without a domestic climate policy (Jaffe et al., 2009).

These competitiveness effects have more than just economic consequences. The potential for relocating emissions-intensive activities to unregulated countries would result in higher emissions in these countries than they would have experienced otherwise. This "emissions leakage" would undermine the environmental benefits of the domestic climate policy and lower societal welfare. Moreover, implementing a public policy that results in both job loss and lower-

than-expected environmental benefits could weaken public and political support for mitigating greenhouse gas emissions.

Policymakers have several options for addressing these competitiveness risks. They could impose tariffs reflecting the embedded carbon emissions in imports, such that domestically produced goods and their foreign competitors face a common carbon price (Weisbach, 2015; Agan et al., 2015). Climate policy could direct benefits to potentially vulnerable firms, such as through free allowance allocations in cap-and-trade programs or targeted tax credits (Gray and Metcalf, 2015; Aldy and Pizer, 2009). Some northern European carbon tax programs have explicitly exempted energy-intensive manufacturing from their carbon tax (Aldy and Stavins, 2012). Policymakers could work through multilateral negotiations to ensure that major trade partners undertake comparable domestic emissions mitigation policies. They could take multilateral coordination a step further by linking domestic mitigation programs among trade partners, which could yield a common carbon price for firms operating under linked programs.

These policy options, however, carry their own risks. They may run afoul of current obligations under the World Trade Organization (Trachtman, 2015). The design of such policies may result in a loss in social welfare and limit the ability of the government to offset potentially regressive impacts of pricing carbon. Competitiveness policies may also have important implications for ongoing international climate negotiations. Finally, the choice and design of competitiveness policies may entail political risks that could also weaken support for the broader domestic climate change policy program.

In this paper, I elaborate in more detail the potential competitiveness risks of a domestic carbon pricing policy, drawing from an extensive theoretical, modeling, and statistical literature. I then examine the potential risks and pitfalls associated with policy responses intended to

address competitiveness. Based on this context, the paper concludes with a framework for considering the economic, environmental, legal, diplomatic, and political factors at play in the design of policy approaches to address the competitiveness concerns of climate change policy.

II. COMPETITIVENESS RISKS

The prospect that heterogeneity in the carbon price among countries could impose adverse competitiveness effects on firms in the high carbon price domestic programs suggests that climate policy entails economic, environmental, and political risks. Moreover, such competitiveness pressures can reduce the social welfare of domestic climate policy.

A. Economic Risks

The concerns about the competitiveness effects of climate change policy are an extension of the pollution haven hypothesis, which suggests that firms relocate economic activity from high regulatory cost to low regulatory cost countries. Jaffe et al. (1995) describe the pollution haven hypothesis in their early survey of this economic literature:

The conventional wisdom is that environmental regulations impose significant costs, slow productivity growth, and thereby hinder the ability of U.S. firms to compete in international markets. This loss of competitiveness is believed to be reflected in declining exports, increasing imports, and a long-term movement of manufacturing capacity from the United States to other countries, particularly in “pollution-intensive” industries (p. 133).

While differential carbon prices, *ceteris paribus*, would result in adverse competitiveness effects, in practice everything else is not equal. Other factors determining investment, relocation,

and trade may dominate the impacts of a carbon price on the inputs to production (Jeppesen et al., 2002). For example, evolving differences in labor costs or exchange rates may drive these decisions. Moreover, the continuing benefits of a firm's current location—such as access to appropriately skilled labor, natural resources, and capital—may exceed the incremental costs of the carbon price gap (Antweiler et al. 2001). Ederington et al. (2005) illustrate how the degree to which an industry is “footloose” affects decisions to relocate to low regulatory cost countries. For example, a firm may have initially located its factories near the major markets for its goods, and the transportation costs associated with relocating to another country may not justify shifting operations abroad. These transportation costs may be even more substantial in the future if international transportation also bears a carbon price or shadow carbon value, given potential emissions mitigation regulations under the International Maritime Organization (IMO) and the International Civil Aviation Organization (ICAO).¹ In addition, firms in their current locations may benefit from agglomeration economies, such as from their proximity to other firms that produce their inputs or purchase their outputs. Further, the large fixed costs in factories and other physical structures may deter relocation. Ederington et al. (2005) find empirical evidence that these measures of “footlooseness” mitigate the potential competitiveness effects of environmental regulatory costs for US manufacturing firms.

Since the most pollution-intensive industries tend to be relatively immobile by these measures of “footlooseness,” the empirical literature typically finds quite limited impacts of environmental regulations on international competitiveness. Levinson and Taylor (2008) show that US pollution abatement costs in the 1970s and 1980s increased net imports in the manufacturing sector from Mexico and Canada. The estimated increase in net imports roughly

¹ For more details on greenhouse gas emissions policies under the IMO and ICAO, refer to <http://www.imo.org/en/MediaCentre/HotTopics/GHG/Documents/Shipping%20and%20climate%20change.pdf> and <http://www.icao.int/environmental-protection/Pages/climate-change.aspx>.

equaled about 10 percent of the total increase in bilateral trade for both Mexico and Canada, suggesting that other factors played much more substantial roles in the evolution of trade among the North American trading partners. An extensive literature on the competitiveness effects of environmental policies that vary in stringency across the US states has shown more significant impacts on domestic firm location and output (Henderson, 1996; Greenstone, 2002). Kahn and Mansur (2013) find even larger effects of energy prices on manufacturing employment when looking at adjacent counties. Deschênes (2012) also finds relatively larger labor market impacts in an analysis focused on variations in state-level electricity prices on employment across all sectors in a state-by-year statistical analysis for the United States. Deschênes (2012) estimates an electricity price–employment elasticity of -0.1 to -0.16 . Based on these results, he suggests that the 2009 Waxman-Markey Bill (HR 2454, 111th Congress) would have lowered employment by about 0.5 percent. The larger *domestic* competitiveness effects may reflect the fact that labor costs and availability of capital do not vary much across US states and counties, and transportation costs are less important, relative to the international context. In Sub-section II.C, we return to these analyses by Kahn and Mansur, Deschênes, and several additional studies and assess their implications under a $\$15/\text{tCO}_2$ price policy. Finally, it's important to recognize that simulations of unilateral carbon pricing policies likely represent the upper bound on competitiveness impacts in a world with a growing number of domestic mitigation programs as countries implement their mitigation pledges under the 2015 Paris Agreement.

This empirical literature has focused on retrospective analyses of US environmental regulations. The absence of a domestic CO_2 regulatory or taxation regime precludes taking exactly the same approach to evaluate the competitiveness effects of climate policy. The popular alternative has been to use applied computable general equilibrium models to simulate potential

competitiveness impacts of pricing carbon. The US Environmental Protection Agency (EPA 2009) estimated that energy-intensive manufacturing sector imports from developing countries would increase by 1–2 percent over the first decade of the Waxman-Markey Bill.² The Interagency Competitiveness Analysis Team (2009) estimated that a \$20 per ton CO₂ price would increase net imports about 1.5 percent for chemicals, cement, bulk glass, and iron and steel, and a little more than 2 percent for aluminum. Ho et al. (2008) modeled the output, consumption, and trade impacts of a \$10 per ton CO₂ price implemented unilaterally in the United States. They found that the CO₂ price drives down manufacturing output by 1.3 percent in chemicals and plastics, 1.1 percent in primary metals, and 0.9 percent in nonmetallic minerals. Approximately half of the decline in domestic production for these industries is offset by an increase in net imports from countries that are not implementing emission mitigation policies.

The Stanford Energy Modeling Forum (EMF) coordinated an evaluation of border tax adjustments with global energy-economic models developed by scholars in the United States, Europe, and Asia. This EMF-29 exercise found modest impacts of unilateral climate policy on energy-intensive manufacturing. In evaluating a unilateral climate policy that delivered, on average across a dozen models, a carbon price of \$40/tCO₂, these models found that the energy-intensive, trade-exposed industries' output fell by about 2.5 percent (Bohringer et al., 2012).

The impact of a price on carbon will also differ across industries depending on the extent to which they use energy, and fossil fuel energy in particular, as a production input. Aldy and Pizer (2015) employ a 35-year panel of about 450 US manufacturing industries to estimate how changes in energy prices will likely impact manufacturing output and net imports. Using the estimated energy price–output and energy price–net import relationships, they simulate the

² This is for modeling scenario 4, which excludes consideration of output-based allowance allocations to energy-intensive trade-exposed manufacturing industries.

competitiveness impacts of a \$15 per ton carbon dioxide price. They find that energy-intensive industries bear much larger adverse output impacts than non-energy-intensive industries under this climate policy—ranging from 3 to 5 percent for steel, chemicals, aluminum, cement, bulk glass, and paper industries—but the change in net imports represents no more than about one-sixth of the decline in output. The changes in production under this carbon price are dwarfed by annual variation in output in energy-intensive industries.

Since the median energy intensity in the US manufacturing sector is about 1.8 percent, the average industry, prior to any adjustments in production, would experience about a 0.2 percent increase in expenditures relative to value of shipments under a \$15/tCO₂ price. As Aldy and Pizer (2014, 2015) show, the average manufacturing industry would experience quite small and statistically insignificant impacts on employment (–0.2 percent) and value of shipments (–1.5 percent) under such a carbon price. In their analyses, four-fifths of the manufacturing sector would not experience statistically significant or economically meaningful impacts from a carbon price on employment or value of shipments. In contrast, the most energy-intensive industries, such as iron and steel, bulk chemicals, aluminum, cement, paper, and bulk glass, would be expected to bear statistically significant adverse competitiveness effects on employment and production. Aldy and Pizer (2014) estimate adverse employment impacts ranging from –0.4 to –2.2 percent for these energy-intensive industries under a \$15 per ton carbon price. Aldy and Pizer (2015) find larger impacts on production, ranging from –3 to –5 percent for these industries. Of course, the competitiveness effects are not simply the gross reduction in employment or production. Some of these declines could reflect reductions in consumption of goods manufactured by these industries. For example, if a carbon price increases the price of steel produced by domestic firms, an automaker may choose to substitute steel from foreign firms or

explore ways to economize on its use of steel in production. If transportation costs, differences in product quality, capacity constraints, or other factors limit the opportunities for increasing net imports, then the automaker may try to reduce the amount of steel it uses in making a car.

An explicit assessment of net imports could then shed light on the extent to which a carbon price would result in adverse competitiveness effects rather than simply a reduction in domestic consumption. Aldy and Pizer (2015) show that the increase in net imports is much smaller than the decline in production under a carbon price. Only about one-sixth of the fall in production—less than 1 percent—is associated with increasing net imports for the most energy-intensive industries. When accounting for the change in net imports, the employment impacts amount to less than 4,000 jobs under a \$15/tCO₂ carbon price (Aldy and Pizer 2014).

These results have two important implications for the design of competitiveness policies. First, given that only the most energy-intensive industries bear statistically significant impacts from pricing carbon, cost-effective competitiveness policies would target those energy-intensive industries. Second, the economically modest impacts of a carbon price on net imports—that is, on competitiveness—suggest that the economic benefits of targeted competitiveness policies may also be relatively modest.

B. Environmental Risks

Suppose that a domestic carbon price causes a steel mill to close in Ohio, while new steel mill capacity comes online in an Indian state that does not impose a carbon price on its energy-intensive factories. Global steel production would remain unchanged, but a larger fraction of this global capacity would operate in markets not subject to a carbon price. The Ohio mill's

emissions would have shifted to India, resulting in no environmental benefit associated with the job loss and the production decline of closing that facility.

This so-called emissions leakage undermines the environmental benefits of the domestic carbon pricing policy. The extent to which this form of leakage would offset domestic greenhouse gas abatement will depend in part on the fraction of an economy's emissions subject to trade substitution. For example, many sectors of the domestic economy have no foreign substitute—household heating and lighting, commuting to work, and services consumption such as entertainment, lodging, and dining, to name just a few. This form of emissions leakage will likely affect only tradables. Aldy (2009) estimates that only about 15 percent of the US economy's emissions are associated with tradable manufactured goods. After accounting for the focus of the competitiveness impacts on energy-intensive industries discussed above, this leakage would likely impact less than 10 percent of US emissions.

It is important to distinguish emissions leakage resulting from competitiveness effects from emissions leakage that may occur through other channels. For example, a domestic carbon price would raise the price of energy. As consumers respond by conserving energy, reducing energy-consuming activities, and investing in more energy-lean capital, domestic fossil fuel consumption declines relative to what it would have been in the absence of the policy. By lowering fossil fuel demand, the price for fossil fuels exclusive of the carbon price will fall. Consumers in other markets who do not face a carbon price would likely respond to the lower fossil fuel prices by increasing their consumption of these fossil fuels. In effect, the conservation and efficiency response to a carbon price in one market weakens the incentive for such conservation in markets without a carbon price as fuel prices in global energy markets respond to the behavioral change in the markets with carbon pricing. As discussed below, leakage through

global energy markets dominates the leakage through competitiveness effects. As a result, policies to address competitiveness effects will mitigate only a fraction of the anticipated emissions leakage from a domestic carbon pricing policy.³

The leakage of emissions via competitiveness effects would increase the costs per ton of emissions abatement and reduce the net social benefits of the domestic climate policy. The costs of the climate policy would reflect the resource costs associated with reducing emissions—such as switching to low- and zero-carbon power technologies, investing in more energy-efficient equipment, and so on—and the costs of closing down manufacturing capacity, but only the former would reduce emissions.⁴ By undermining cost-effectiveness, the competitiveness effects would also reduce social welfare of the domestic carbon pricing policy. For example, if policymakers set the price on carbon equal to the marginal benefit of carbon reductions to maximize net social benefits, but failed to account for competitiveness-induced emissions leakage, then the realized marginal cost of abating a ton of carbon would likely exceed the carbon price set in the policy and the marginal benefits of reducing emissions.

Global computable general equilibrium models can provide estimates of emissions leakage under domestic carbon pricing policies. The Interagency Competitiveness Analysis Team (2009) estimated that a \$20/tCO₂ price would result in emissions leakage of about 15 million metric tons of carbon dioxide in energy-intensive, trade-exposed industries. A recent multimodel comparison exercise organized by the Stanford Energy Modeling Forum evaluated

³ The exception is in the case of policy efforts through multilateral negotiations to ensure that all trade partners implement a domestic carbon pricing policy.

⁴ Some analyses suggest that emissions leakage from competitiveness effects could have a greater than one-to-one ratio of emissions increase in unregulated markets to emissions reductions in regulated markets. For example, if a steel mill in the United States that uses X units of fossil fuel per unit of production closes down in response to the carbon pricing policy, and a steel mill in a developing country that uses 1.1X units of fossil fuel per unit of production increases production to match that of the US mill, then the leakage rate for that steel mill would be 110 percent. It is also possible that the increase in foreign capacity could take advantage of lower-emitting energy sources and that the leakage rate would be less than 100 percent.

the environmental, economic, and trade impacts of unilateral, domestic carbon pricing policy and of such policies coupled with border tax adjustments (Bohringer et al., 2012). Over the twelve models participating in this exercise, the emissions leakage rate—defined as the ratio of the change in foreign emissions to the change in domestic emissions—ranged from 5 to 19 percent, with an average of 12 percent across all models for scenarios without a border tax adjustment. The modelers found that a border tax adjustment reduces, but does not eliminate, emissions leakage. Imposing a border tax on the carbon content of imported goods equal to the domestic carbon price reduced leakage to 8 percent on average, with a range of 2 to 12 percent across the models. These results suggest that the second leakage mechanism, through global fossil fuel markets, plays an important and apparently dominant role in emissions leakage under unilateral carbon pricing policy.

C. Synthesis of Studies on Economic and Environmental Risks

To place some of the statistical and structural modeling literature in a common policy frame and examine the implications for economic competitiveness and emissions leakage, I have identified five studies to assess in the context of a common carbon pricing policy. These studies vary in terms of their empirical approaches, including statistical analyses with identification through panel-based methods and regression discontinuity models, as well as the US EIA National Energy Modeling System and a computable general equilibrium model (Table 1). These studies also vary in terms of their outcome measures, including industry-level production, employment, and net imports, primarily within manufacturing, although a few studies are economy-wide. Some studies indirectly address carbon by evaluating the relationship between

energy prices or electricity prices and these outcomes, while several explicitly model a carbon tax. The underlying data for estimation and calibration also vary across the studies.

I use the estimated elasticities for energy (electricity) prices and outcomes from the statistical models and the outputs of the structural simulation models to simulate the impacts of a \$15/tCO₂ price on production, competitiveness-related production, and emissions leakage in Table 2 and on employment and competitiveness-related employment in Table 3. I estimate the energy and electricity price changes relative to a no-policy reference case for an economy-wide \$15/tCO₂ tax based on the US EIA Annual Energy Outlook 2014, which I interpolated from its two side cases of \$10/tCO₂ and \$25/tCO₂. I use these price impacts to simulate the effects of this carbon tax for select energy-intensive trade exposed manufacturing industries and for total manufacturing. I also directly use the interpolated impacts on production and employment from EIA (2014), as well as extrapolate impacts on production, employment, and net imports for Ho et al. (2008) from their \$10/tCO₂ carbon tax analysis using a computable general equilibrium model. Three studies—Aldy and Pizer (2014), Aldy and Pizer (2015), and Ho et al. (2008)—estimate impacts on net imports by industry, and these are used to produce a range of competitiveness impacts for production and employment. In other words, I apply the estimated shares of reduced production associated with an increase in net imports (as opposed to a decrease in domestic consumption) to the direct production and employment impacts of the carbon price to produce competitiveness effects.⁵ These competitiveness effects for production can then be used to estimate the emissions leakage by each energy-intensive manufacturing industry, based on the 2010 US EIA Manufacturing Energy Consumption Survey (Agan et al., 2015).

⁵ The employment analyses are predicated on the assumption that the share of decline in production due to an increase in net imports translates one-for-one to the share of decline in employment due to an increase in net imports.

Table 2 focuses on the three studies with production impacts and shows direct effects of a \$15/tCO₂ pricing policy on the order of 2 to 3 percent for most energy-intensive manufacturing industries in the Aldy and Pizer (2015) statistical analysis, but about 1 percent based on the simulation models (EIA, 2014; Ho et al., 2008). The average production impacts across the entire manufacturing sector are less than 1 percent in all three studies. After accounting for the fact that only some of the decline in production is due to an increase in net imports, the net production effects due to competitiveness are much smaller, ranging from near zero to less than ½ of 1 percent among the simulation models and generally not much more than 1 percent based on the statistical analysis. These changes in production are consistently small across the three different empirical approaches, in light of the historic volatility in both production and net imports experienced by these industries (Aldy and Pizer 2015). The environmental impact is quite modest as well, with estimated leakage ranging from about 1 million to 7 million metric tons of carbon dioxide based on Aldy and Pizer (2015), and 3 million metric tons or less based on the simulation models. These impacts represent an economy-wide leakage rate of only a few percentage points based on the estimated emissions reductions of a \$15/tCO₂ pricing policy in EIA (2014).

Table 3 focuses on the employment impacts of pricing carbon, and the results follow a similar pattern as for production. The statistical analyses tend to show larger impacts (as much as several percentage points) than the simulation models (less than ½ of 1 percent), although most industries would appear to experience a smaller percentage reduction in employment than in production. The Kahn and Mansur (2013) study finds larger-magnitude declines in employment, although it is based on a model that shows that the manufacturing industry with the median energy intensity would witness an increase in employment under an electricity price increase

expected with a \$15/tCO₂ pricing policy. The manufacturing-wide employment effects are no more than 1/3 of 1 percent across all four studies, a little less than the economy-wide employment effect of 1/2 of 1 percent estimated by Deschênes (2012). The net employment effects due to competitiveness are also quite small, given historic variation in these industries, and are on the order of several tenths of 1 percent for three of the four studies and about 1 to 2 percent in Kahn and Mansur. Given 2014 employment levels in these industries, the competitiveness-related employment impacts aggregated over all energy-intensive manufacturing industries in the simulation models are less than 2,000 jobs and range from about 1,000 to 17,000 jobs for the statistical analyses.⁶ The upper bound of competitiveness-related employment job losses for all manufacturing industries is less than 10 percent of the growth in manufacturing employment over 2013–2014.

Across a variety of empirical approaches based on various datasets for calibration and estimation, these five studies suggest fairly small competitiveness-related economic and environmental impacts of a \$15/tCO₂ pricing policy. They also make it clear how the majority of the adverse economic impacts for energy-intensive manufacturing industries reflect declines in domestic consumption, not an increase in net imports.

D. Political Risks

The competitiveness effects of domestic climate policy could pose political risks to the broader carbon pricing policy. If a climate change policy raises energy prices and drives the relocation of manufacturing capacity to developing countries, but does not meaningfully reduce greenhouse gas emissions due to leakage, then business stakeholders could criticize the policy

⁶ While Kahn and Mansur show the largest declines in energy-intensive manufacturing employment, their results suggest net employment gains for non-energy-intensive manufacturing.

for delivering high costs and causing job loss without environmental benefits. Some environmental advocates who oppose carbon pricing policies may also use the prospect of such an outcome to criticize the domestic policy with the intent of refocusing mitigation efforts on command-and-control regulations.

This illustrates the importance of empirical analysis in informing the political debate on carbon pricing. If the economic and environmental impacts of competitiveness are small, then that has different political implications than if they are quite large. Moreover, stakeholders may conflate, or at least not differentiate between, the competitiveness effects from the domestic consumption impacts described at the end of Sub-section II.A. Empirical analysis could clearly delineate these impacts. Finally, the political dimension of competitiveness suggests that stakeholders could be invited to contribute their own analyses of competitiveness to further enrich and inform the discussion of policy needs, policy design, and subsequent implementation.

III. RISKS FROM COMPETITIVENESS POLICIES

The primary benefit of a well-designed competitiveness policy is that it would mitigate and potentially eliminate the competitiveness risks described in Section II. Nonetheless, competitiveness policies also carry risks, in terms of their potential impacts on the distribution of the benefits and costs of carbon pricing policy, the efficiency of pricing carbon, and international relations in multilateral trade and climate policy contexts.

A. Distributional Risks

Several policy options for mitigating competitiveness risks involve either the targeted allocation of tax revenue (in the case of a carbon tax or a cap-and-trade with auction program) or

the targeted allocation of emissions allowances (in the case of a cap-and-trade program without an auction). For example, the 2009 Waxman-Markey Bill provided energy-intensive trade-exposed manufacturing industries with free allowances as a function of their production.⁷ According to EIA (2009) and the Interagency Competitiveness Analysis Team (2009), these output-based allowances corresponded to about \$18 billion in annual value. In a similar fashion, a tax credit premised on output by energy-intensive, trade-exposed industries would direct a fraction of the revenue raised by the carbon tax to targeted industries.

Such policies impose two kinds of distributional risks. First, by dedicating a fraction of revenues to energy-intensive industries, policymakers forgo opportunities for using the revenues for other purposes, such as lowering income tax rates, financing broader tax reform, delivering transfers to low-income households, or supporting energy research and development. Depending on the economic incidence of such targeted support between workers and the owners of the firms, these competitiveness policies may result in a less progressive carbon pricing policy than what could be possible otherwise. Second, the design of targeted support for energy-intensive industries risks being excessively generous. Business stakeholders calling for such targeted support may, as noted above, focus on the aggregate impacts of carbon pricing on energy-intensive industries, not simply the competitiveness effect. The economic value of the free allowances set aside in the Waxman-Markey Bill illustrates the potential for excessive compensation. In that case, energy-intensive manufacturing firms would have received emissions allowances valued at \$18 billion in 2014, which would have exceeded the reduction in the value of shipments estimated for energy-intensive industries by EIA (2009) and their increased expenditures on energy. In separate modeling analysis, the Interagency Competitiveness

⁷ In a separate provision, the bill provided free allowances to refineries to address concerns that the envisioned cap-and-trade program would adversely affect these refineries' competitive position.

Analysis Team (2009) found that these free allowances would have reduced the marginal production costs for several industries, including chemicals and pulp and paper, even in the presence of a \$20/tCO₂ allowance price.

Establishing the precedent for targeted relief in a carbon pricing program creates a difficult political economy. While economists tend to focus on “triangles” (the social welfare or deadweight loss of a public policy), lobbyists and stakeholders focus on “rectangles” (the potential transfers of economic value or revenues under a public policy). As a result, ad hoc adjustments to policy design, such as the addition of free allowances to refineries as the Waxman-Markey Bill moved through the markup process in committee, can reflect the political influence of stakeholders (Cragg et al., 2013). It can also highlight the challenge in where to draw the line in providing relief, which can further skew the distributional impacts of the carbon pricing policy in favor of energy-intensive industries or other influential special interests.

B. Efficiency Risks

The implementation of competitiveness policies may undermine the economic efficiency of the carbon pricing policy. Targeting economic value to energy-intensive, trade-exposed firms as a function of their production, through tax credits or free emissions allowances, creates an implicit output subsidy (Fischer and Fox, 2012). The effective carbon price that such energy-intensive firms face is lower than the carbon price set in statute (under a carbon tax) or realized in secondary markets for tradable emissions allowances (under a cap-and-trade program). Households paying more for electricity or gasoline, as a result of the carbon price, would face a higher carbon price than these firms receiving the targeted support. This is inconsistent with a fundamental premise of carbon pricing policies, which is to apply a common carbon price across

all emissions sources (or upstream on the carbon content of all fossil fuels) in order to minimize the costs of abating emissions. By delivering heterogeneous effective carbon prices, the output-based competitiveness measures reduce the net social benefits of the carbon pricing policy. Such an approach results in either greater emissions under a carbon tax (since the tax is effectively lowered for energy-intensive firms) or the need for greater abatement by emissions sources that are not targeted with free emissions allowances as a function of their output under a cap-and-trade program, relative to a simple carbon pricing policy without such a competitiveness policy.

The complexity of competitiveness policies could undermine the economic efficiency of the carbon pricing policy (see also Weisbach, 2015). The combination of complex policy design and potentially large economic rents at play creates incentives for firms to exploit the complexity to their advantage. If past competitiveness policies (such as the Waxman-Markey approach to output-based allowance allocations) are any guide, then firms may have incentives for managing and reporting their data in a way that increases their likelihood of receiving the targeted transfers.

The complexity may create opportunities for foreign firms to seek out ways of avoiding the border tariff. For example, firms from “tariff” countries could pursue a transshipping strategy through a third, “nontariff” country. Suppose that the United States imposes a border tax on the carbon content of goods from N countries, but exempts firms based in the EU from the border tax because of the European Union’s Emissions Trading System. Firms in these N countries could increase exports to the EU, and EU-based firms in the same industries could send more of their goods to the United States (instead of for their domestic markets). The implementation of the border tax also raises questions on how to evaluate the policies in other countries (see also Aldy and Pizer, 2016; Agan et al., 2015). How should the US border tax account for the fact that some electricity sources in a given country are zero-carbon (e.g., hydropower in China) and

some sources are carbon-intensive (e.g., coal-fired power in China) even in the presence of a domestic emissions mitigation program in that country? Given the heterogeneity in national emissions goals and domestic mitigation programs under the United Nations Framework Convention on Climate Change (UNFCCC) Paris Agreement, how would the United States determine whether energy-intensive manufacturers in other countries face “comparable” carbon pricing to a US carbon tax? How would this assessment be affected by volatility in currency exchange rates or by high-frequency volatility in the prices of emissions allowances in those countries that implement a cap-and-trade program (such as the European Union and China)?

Finally, the prospect of border tax adjustments could elicit adverse reactions from trade partners. Trade partners could respond by imposing import tariffs on US goods, which would adversely affect the manufacturers of those goods. This would serve as an additional domestic cost of the carbon pricing regime for the given emissions reductions associated with the policy.

C. International Relations Risks

As Trachtman (2015) explores in detail, there are potential legal risks under the World Trade Organization (WTO) with several of the competitiveness policies that policymakers may consider. Some trade policy experts have reservations about a border tax adjustment—even if it can be crafted in a WTO-consistent manner—because of the potential diplomatic and political ramifications for the relatively fragile ongoing trade negotiations. Some of the more contentious issues in the WTO fall along a developed-developing country divide, and some developing countries would perceive a border tax adjustment as targeting their export industries.

If a border tax adjustment is found to be inconsistent with the WTO, then that creates another set of problems for the United States. It would require modifications, if not elimination,

of the border tax adjustment unless the United States is willing to bear the countervailing duties that would be imposed on US exports. The political economy of such countervailing duties would make it unlikely that the United States would continue with its border tax adjustment under such a finding. Moreover, an adverse WTO finding harms the US reputation in trade talks by illustrating how the United States uses trade law to protect its domestic manufacturing. This would especially be the case if the border tax adjustment appears to be designed to protect domestic industry rather than designed to protect the environment.

Competitiveness policies may also spur a backlash in the international climate negotiations. In particular, a border tax adjustment could draw the ire of China and India, among other countries. In recent years, China and India have unsuccessfully advocated for prohibitions on such trade measures in the annual UN climate talks.⁸ The prospect of its exports facing a border tax adjustment could cause China to reconsider its recent cooperation with the United States, evident in their November 2014 and September 2015 bilateral policy announcements.⁹ Some developing countries may also argue that a border tax adjustment imposes an unfair burden on their exports, given what they view as the United States' unique contribution to and responsibility for climate change.

On the other hand, the prospect of a border tax adjustment could create the incentive for US trade partners to step up and implement their own domestic emissions mitigation programs. Chinese government officials have been aware of the US concerns regarding competitiveness and climate policy for quite some time. With China's pilot cap-and-trade programs setting the

⁸ For example, the December 5, 2015, draft text of the Paris Agreement included a bracketed paragraph stating that “[d]eveloped country Parties shall not resort to any form of unilateral measures against goods and services from developing country Parties on any grounds related to climate change” (paragraph 17, FCCC/ADP/2015/L.6/Rev.1). This bracketed text did not secure consensus of the negotiators and was dropped from the final version.

⁹ See <https://www.whitehouse.gov/the-press-office/2014/11/11/us-china-joint-announcement-climate-change> and <https://www.whitehouse.gov/the-press-office/2015/09/25/us-china-joint-presidential-statement-climate-change>.

foundation for nationwide expansions later this decade, China is pursuing a domestic carbon pricing policy that could exempt its exports from a border tax adjustment. The outstanding question is whether a border tax adjustment becomes the norm in countries with domestic carbon pricing policies, or whether it serves as the stick, rarely used, to encourage substantial emissions mitigation programs among trade partners.

Let me close by noting that the first-best approach to addressing competitiveness—one that avoids these distributional, efficiency, and international relations risks—is the effort focused on securing meaningful domestic climate policies among all trade partners in multilateral climate negotiations. If all trade partners impose a common carbon price on their businesses' emissions, this would eliminate the price gap that drives the competitiveness effects. The December 2015 Paris Agreement includes emissions mitigation contributions from nearly 190 countries, as well as a process by which countries will update their domestic programs and goals periodically, which serves as the first meaningful, truly global step to ensure mitigation efforts among all trade partners. The challenge going forward will be in designing a system of transparency that can permit the comparability of these mitigation efforts in a way that can clearly identify whether the no-competitiveness effects outcome of a common effective carbon price has been realized (Aldy, 2014; Aldy and Pizer, 2016).

IV. FRAMEWORKS FOR EVALUATING COMPETITIVENESS POLICIES

Sections II and III have provided the foundation for framing policy evaluation. Section II highlighted the potential economic, environmental, and political risks associated with the competitiveness effects of domestic carbon pricing policy. The studies employing structural models and statistical analyses find relatively modest economic and environmental impacts from

unilateral domestic emissions mitigation policies. Nonetheless, competitiveness policies that can reduce or eliminate these impacts, as noted at the beginning of Section III, would deliver societal benefits and remove one political rationale for opposing carbon pricing. Competitiveness policies carry their own risks, and these may result in meaningful economic, political, and diplomatic costs. Within this context, I offer two frameworks by which policymakers, stakeholders, analysts, and the public could evaluate competitiveness policies.

A. Social Welfare Framework

One could employ a standard framework for assessing the benefits and costs of the policy options. The objective under this approach would be to choose the competitiveness policy that maximizes social welfare (i.e., net social benefits). This would begin with a clear description of the public policy problem and rationale for policy intervention. The prospect of insufficient multilateral coordination in designing and implementing domestic climate programs could result in a carbon price differential between the United States and its trade partners. The subsequent competitiveness effects could take the form of economic costs—through trade channels as evident in changes in net imports—and reduce environmental benefits via emissions leakage. Thus the policy problem is narrower than industries bearing costs under a carbon pricing policy.

The benefits of competitiveness policies will reflect two factors. First, the magnitude and timing of competitiveness effects will be a function of the carbon price gap—the differential between the domestic carbon price and the carbon price prevailing in trade partners’ economies. An array of structural models and statistical models in the peer-reviewed literature can produce estimates of the economic and emissions impacts resulting from competitiveness pressures. These estimated impacts represent the baseline or “no competitiveness policy” counterfactual by

which to assess the impacts of each of the policy options. The second factor is the assessment of the efficacy of a given policy option. Again, some of the existing modeling tools can be used to estimate the impacts of competitiveness policies. These would account for how the policy design may impact not only competitiveness but also other emissions- or economic-related outcomes. For example, an output-based tax credit or rebate would subsidize production, as noted above, and thus the policy’s impact on reducing net emissions may be smaller than an alternative instrument that does not subsidize the production margin.

By definition, such tools simplify the economic and policy environment in order to model the response to a policy intervention. One of the key simplifications lies in the institutional design of the policy instrument. For example, most structural models that can be used to evaluate competitiveness effects and competitiveness policies are set up to have a single, representative “energy-intensive” industry (e.g., see the models summarized in Bohringer et al., 2012).¹⁰ In this case, a government policy to target an output-based tax credit or a border tax adjustment for energy-intensive industries would appear, in the model, to map one-to-one with energy-intensive industries. How policymakers identify firms eligible for tax credits—especially if some of their activities fall into traditionally classified energy-intensive industries, while other activities do not—or industries to be covered by a border tax adjustment is subject to political discretion over eligibility criteria that could substantially alter the policy’s breadth, costs, and benefits (Agan et al., 2015). Yet these kinds of details are too specific to be represented well in most models.

This note of caution about the institutional design motivates serious consideration of basic principles of tax policy, especially with respect to administrative simplicity and feasibility. A complex competitiveness instrument may be costly and difficult for the government to

¹⁰ In contrast, see Fischer and Fox (2012) and International Competitiveness Analysis Team (2009) for analyses that illustrate the implications of disaggregating the representation of energy-intensive industries in an economic model.

enforce, as well as confusing for businesses to operate under. If a complicated instrument spurs two otherwise similar businesses to pursue alternative strategies—because their managers interpret the policy differently—then this is likely to lower social welfare. Complex instruments also provide potential opportunities for firms to exploit unintended provisions or loopholes, and these unexpected actions could also lower social welfare. A simple, transparent policy instrument is more likely to be implemented as intended and to deliver on the anticipated outcomes.

In this framework, policymakers will also need to consider the potential costs of the competitiveness policy. For example, an output-based tax credit will require the government to raise revenues in order to finance the policy. Revenue raising typically occurs through the tax code in a way that distorts the returns to capital and labor. The administration of the policy will also impose some costs on the government, as well as on those participating under the policy (such as the costs of recordkeeping and reporting). These costs could be explicitly accounted for, quantified, and weighed against the benefits of the policy.

Two risks of competitiveness policies, however, may not fit neatly into a benefit–cost framework. First, the trade policy risks, in terms of potential violations of obligations under the WTO and broader reputational impacts, may be difficult to quantify or monetize. Some policymakers with a strong preference for protecting American trade policy interests may want to impose a constraint on the analysis, such as permitting consideration of only those policy options viewed as “highly likely” to be consistent with trade law. Other policymakers may be willing to bear trade policy risks for a competitiveness policy that delivers quite significant economic and environmental benefits. Thus a policy option with large net social benefits would be acceptable to these policymakers even if the policy suffered meaningful trade policy risks.

Second, the distributional impacts of the policy options may be quite important to policymakers but have no bearing on the aggregate net social benefits estimate. The analysis of the benefits and costs could be used to explicitly characterize the distribution of impacts of the policy options. Consideration of distributional impacts could be permitted under a “soft” benefit–cost rule, similar to what executive branch regulatory agencies use in determining whether the benefits “justify” the costs in major regulations.¹¹ Indeed, such distributional analysis is called for (although not frequently conducted) as a part of regulatory review of major regulations in the executive branch (Robinson et al., 2014).

This social welfare framework shares much in common with how the federal government evaluates alternatives under consideration in regulatory policy. The distinction here is that such a framework could be quite usefully applied to policy options that would likely be under consideration at the legislative stage. While the timing, with respect to the policy process, is different, it is otherwise quite similar to how the government assesses the benefits and costs of options in order to inform regulatory decision-making.

B. Political Economy Framework

As an alternative approach, one could employ a political economy framework based on the premise that a new carbon pricing policy can elicit sufficient support in Congress and the White House only if the proposed competitiveness policy is part of a bill. In this case, the objective is a somewhat more vague political revealed-preference standard. If a carbon pricing regime featuring a competitiveness policy secures enough votes in each chamber of Congress and the signature of the president, then the political process effectively reveals its preference for this option. It is possible that several policy options could satisfy the standard of ensuring

¹¹ See Executive Order 12866, Section 1(b)(6).

passage of the carbon pricing legislation. Let us consider a constrained political revealed preference objective that chooses the policy option that minimizes the risks of social welfare loss, adverse distributional outcomes, and trade law challenges, while resulting in the passage of the carbon pricing legislation. It is also possible that, depending on the weights one assigns to each of these constraints, a unique policy option that satisfies all of the constraints may not exist.

This framework explicitly acknowledges the nature of the political process that determines what bills become law. Moreover, it recognizes that competitiveness effects are more of a political issue than an economic issue or, as noted above, an issue of distribution of rents (i.e., allocating the rectangles instead of minimizing the size of the deadweight-loss triangles). As the various modeling and statistical analyses described above indicate, the magnitude of competitiveness effects is fairly small. The estimated increase in net imports under unilateral carbon pricing appears to be dwarfed (by at least one order of magnitude) by the annual variation in net imports for energy-intensive industries (Aldy and Pizer, 2015), suggesting that other economic forces play a much larger role than energy prices in the evolution of trade in manufactured goods. Instead of trying to design the policy that maximizes net social benefits—when the benefits are likely to be relatively modest in comparison with the carbon pricing policy as a whole—this framework would focus on how to use competitiveness policy to leverage sufficient support for a meaningful legislative carbon pricing policy (Fischer and Fox 2011).

While I have expressed the objective of this political economy framework as one that should be constrained by consideration of the potential downside risks of competitiveness policy, it is important to note that the political process could impose such constraints anyway. For example, some members of Congress, who have a strong preference for complying with our trade policy obligations, may support a carbon pricing bill so long as it does not weaken US

positions in trade negotiations or undermine the US reputation in trade law. As a corollary to this, any competitiveness policy that imposes burdens on imports but cannot demonstrate environmental benefits may draw the ire of protrade politicians because of concerns that this would increase the likelihood that another country could successfully challenge the border tax adjustment before the WTO (see Agan et al., 2015; Trachtman, 2015). Alternatively, some politicians may emphasize returning revenue from a carbon tax to families. They may not find appealing the distributional implications of an output-based tax credit (what these politicians may describe as “corporate welfare”) that reduces the potential transfers to families.

Consider the political economy of competitiveness policy in the context of tax reform. A number of analysts have suggested pairing a carbon tax with tax reform (e.g., Aldy, 2013; Morris, 2013), and some analysts have argued that corporate tax reform financed, at least in part, by a carbon tax could elicit bipartisan political support (Taylor, 2015). Lowering the corporate income tax rate may offset some or all of the costs borne by a firm in complying with a carbon tax. This will depend on the nature of the change in corporate tax rates—such as an across-the-board cut versus tailored cuts, as well as changes to other corporate tax provisions—and the effective carbon intensity of a given firm’s production. Even if a lower corporate tax rate could benefit most firms, each individual firm and even small groups of firms (e.g., the steel industry or the cement industry) may have little interest in advocating for a broad, across-the-board cut in corporate tax rates that would benefit a large group of firms (e.g., Olson, 1971).

Moreover, as Stigler (1971) notes, firms may not support direct subsidies if they cannot effectively limit who receives the subsidies, and an across-the-board cut in the corporate income tax rate would fall in this category. Likewise, expanding support for energy-intensive trade-exposed manufacturing to a broader set of industries—such as all manufacturing or more—

would likely lose the interest and advocacy of the most energy-intensive industries (and their workers). The prospect that broader eligibility for output-based tax credits could result in a smaller tax credit would weaken the rationale for any individual firm or industry to advocate for it. A narrowly designed instrument, such as competitiveness policy for energy-intensive, trade-exposed industries, which are a relatively small group of industries and firms, could receive focused and intense political support from business and labor interests, which would make it a necessary element of any final carbon tax legislation.

Such a political economy framework could still benefit, nonetheless, from the kinds of analysis that would be undertaken under the social welfare framework. While this analysis would not feed into a net social benefits calculus, it could play an important role in informing politicians, stakeholders, and the public about the likely impacts of various competitiveness policy options. Transparency about the impacts of these options may increase the likelihood that the political process selects the policy option that minimizes the potential downside risks of competitiveness policy while delivering on passage of the broader carbon pricing legislation.

V. CONCLUSIONS

Domestic carbon pricing policies may create a carbon price gap in which US firms face a higher price on carbon than their competitors located in other countries. This carbon price differential could drive adverse competitiveness effects in the United States, such as higher net imports, lower production among energy-intensive industries, and job loss. Moreover, such competitiveness effects could also undermine the primary motivation of carbon pricing—reducing greenhouse gas emissions—through emissions leakage as emissions-intensive activities

shift to unregulated foreign markets. Imposing costs and job loss in manufacturing industries with diminished environmental benefit could weaken political support for carbon pricing.

Policymakers may choose among a variety of competitiveness policy options intended to mitigate these adverse outcomes. A border tax adjustment or an output-based tax credit (effectively a subsidy for production) could address competitiveness effects. Such approaches, however, also carry potential risks. They may result in less favorable distributional outcomes, undermine cost-effectiveness and economic efficiency, and raise risks in international trade and multilateral climate negotiations.

In this paper, I have reviewed competitiveness risks and the risks posed by competitiveness policies. Drawing on a large and growing economic simulation modeling and statistical analysis literature, I have shown that the economic and environmental impacts of competitiveness appear relatively modest, especially in light of the political attention often focused on this issue. Given the empirical research, I have proposed two frameworks by which policymakers could evaluate competitiveness policy options. First, one could weigh the benefits and costs of various options with the aim of maximizing net social benefits. Second, one could focus on political revealed preference, whereby the objective is to select the policy option that ensures passage of the broader carbon pricing bill in Congress (and subsequent signing into law by the president). Rigorous policy analysis could play an important role in each of these frameworks, and in fact, some policymakers and politicians may prefer to maximize net social benefits of a competitiveness policy subject to its enabling the legislative success of the carbon pricing policy.

Tables

Table 1. Summary of Studies Estimating the Impacts of Carbon Taxes, Energy Prices, and Electricity Prices on US Production and Employment

Study	Empirical approach	Outcome measures	Scope of policy	Scope of analysis	Data for estimation/calibration
Aldy and Pizer 2014	Industry-by-year panel-based statistical analysis	Employment, production, net imports	Variation in electricity prices; simulates power sector \$15/tCO ₂ price	Manufacturing sector	450 industries over 1986–1994 (SIC4/NAICS6)
Aldy and Pizer 2015	Industry-by-year panel-based statistical analysis	Production, net imports	Variation in energy prices; simulates economy-wide \$15/tCO ₂ price	Manufacturing sector	450 industries over 1979–2005 (SIC4/NAICS6)
Deschênes 2012	State-by-year panel-based statistical analysis	Employment	Variation in electricity prices; simulates Waxman-Markey Bill	Economy-wide	50 states over 1976–2007
EIA 2014	NEMS energy-economic structural model	Employment, production	Economy-wide carbon tax: \$10/tCO ₂ and \$25/tCO ₂	Economy-wide, with manufacturing sector details	NEMS model calibrated for Annual Energy Outlook 2014
Ho et al. 2008	Computable general equilibrium model	Employment, production, net imports	Economy-wide carbon tax: \$10/tCO ₂	Economy-wide, with manufacturing sector details	Calibrated to 2002 input-output tables
Kahn and Mansur 2013	County pairs-by-year regression discontinuity statistical analysis	Employment	Variation in electricity prices	Manufacturing sector	21 industries over 1998–2009 (NAICS3)

Table 2. Production Impacts, Competitiveness Effects, and Manufacturing Emissions Leakage of a \$15/tCO₂ Policy

Industry	Gross production impacts (%)			Net production competitiveness effects (%)		
	Aldy-Pizer 2015	EIA AEO14	Ho et al. 2008	Aldy-Pizer 2015	EIA AEO14	Ho et al. 2008
Iron and steel	-1.8	-2.3	-0.8	0 to -0.7	0 to -0.9	0 to -0.3
Chemicals	-2.3	-0.8	-0.9	-0.2 to -1.2	-0.1 to -0.4	-0.1 to -0.5
Paper	-2.2	-0.4	-0.2	-0.1 to -0.6	0 to -0.1	0.0 to -0.1
Aluminum	-3.0	-1.5	-0.8	-0.5 to -1.3	-0.2 to -0.6	-0.1 to -0.3
Cement	-2.8	-1.0	-0.6	-0.3 to -1.3	-0.1 to -0.5	-0.1 to -0.3
Bulk glass	-2.7	-1.0	-0.6	-0.3 to -1.3	-0.1 to -0.5	-0.1 to -0.3
Manufacturing average	-0.9	-0.5	-0.3	0 to -0.5	0 to -0.3	0 to -0.2
EITE CO ₂ leakage (MMTCO ₂)				-1.0 to -7.0	-0.3 to -3.1	-0.3 to -2.4
Share of EIA estimated CO ₂ Reductions at \$15/tCO ₂				0.6 to 4.4	0.2 to 1.9	0.2 to 1.5

Notes: EIA AEO14 reflects linear interpolation of the \$10/tCO₂ and \$25/tCO₂ scenarios. Ho et al. 2008 reflects linear extrapolation from its \$10/tCO₂ scenario. Aldy-Pizer 2015 reflects the energy price increase in EIA AEO14 estimated for the interpolation of a \$15/tCO₂ price. The ranges for the competitiveness effects reflect the industry-specific competitiveness effects estimates in Ho et al. 2008, Aldy-Pizer 2014, and Aldy-Pizer 2015. The EITE CO₂ leakage refers to the industry emissions in the 2010 EIA Manufacturing Energy Consumption Survey for the iron and steel industry (NAICS 331111, 331112, 3312), chemicals industry (NAICS 325), paper industry (NAICS 322), aluminum industry (NAICS 3313), cement industry (NAICS 327310), and bulk glass industry (NAICS 327211).

Table 3. Gross Employment Impacts and Net Competitiveness Effects of a \$15/tCO₂ Policy (%)

Industry	Gross employment impacts				Net employment competitiveness effects			
	Aldy-Pizer 2014	EIA AEO14	Ho et al. 2008	Kahn-Mansur 2013	Aldy-Pizer 2014	EIA AEO14	Ho et al. 2008	Kahn-Mansur 2013
Iron and steel	-0.8	-0.4	-0.5	-5.2	0 to -0.4	0 to -0.2	0 to -0.2	0 to -2.1
Chemicals	-1.2	-0.3	-0.3	-1.6	-0.1 to -0.5	0 to -0.1	0 to -0.1	-0.1 to -0.7
Paper	-1.5	-0.2	-0.1	-4.2	-0.1 to -0.6	0 to -0.1	0	-0.2 to -1.8
Aluminum	-0.8	-0.3	-0.5	-5.2	-0.1 to -0.3	0 to -0.1	-0.1 to -0.2	-0.8 to -2.1
Cement	-0.3	-0.5	-0.3	-2.1	0 to -0.1	-0.1 to -0.2	0 to -0.1	-0.3 to -0.9
Bulk glass	-1.8	-0.5	-0.3	-2.1	-0.2 to -0.7	-0.1 to -0.2	0 to -0.1	-0.2 to -0.9
Manufacturing average	-0.2	-0.3	-0.1	-0.3	0 to -0.1	0 to -0.1	0 to -0.1	0 to -0.1

Notes: EIA AEO14 reflects linear interpolation of the \$10/tCO₂ and \$25/tCO₂ scenarios. Ho et al. 2008 reflects linear extrapolation from its \$10/tCO₂ scenario. Aldy-Pizer 2014 and Kahn-Mansur 2013 reflect the electricity price increase in EIA AEO14 estimated for the interpolation of a \$15/tCO₂ price. The ranges for the competitiveness effects reflect the industry-specific competitiveness effects estimates in Ho et al. 2008, Aldy-Pizer 2014, and Aldy-Pizer 2015.

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