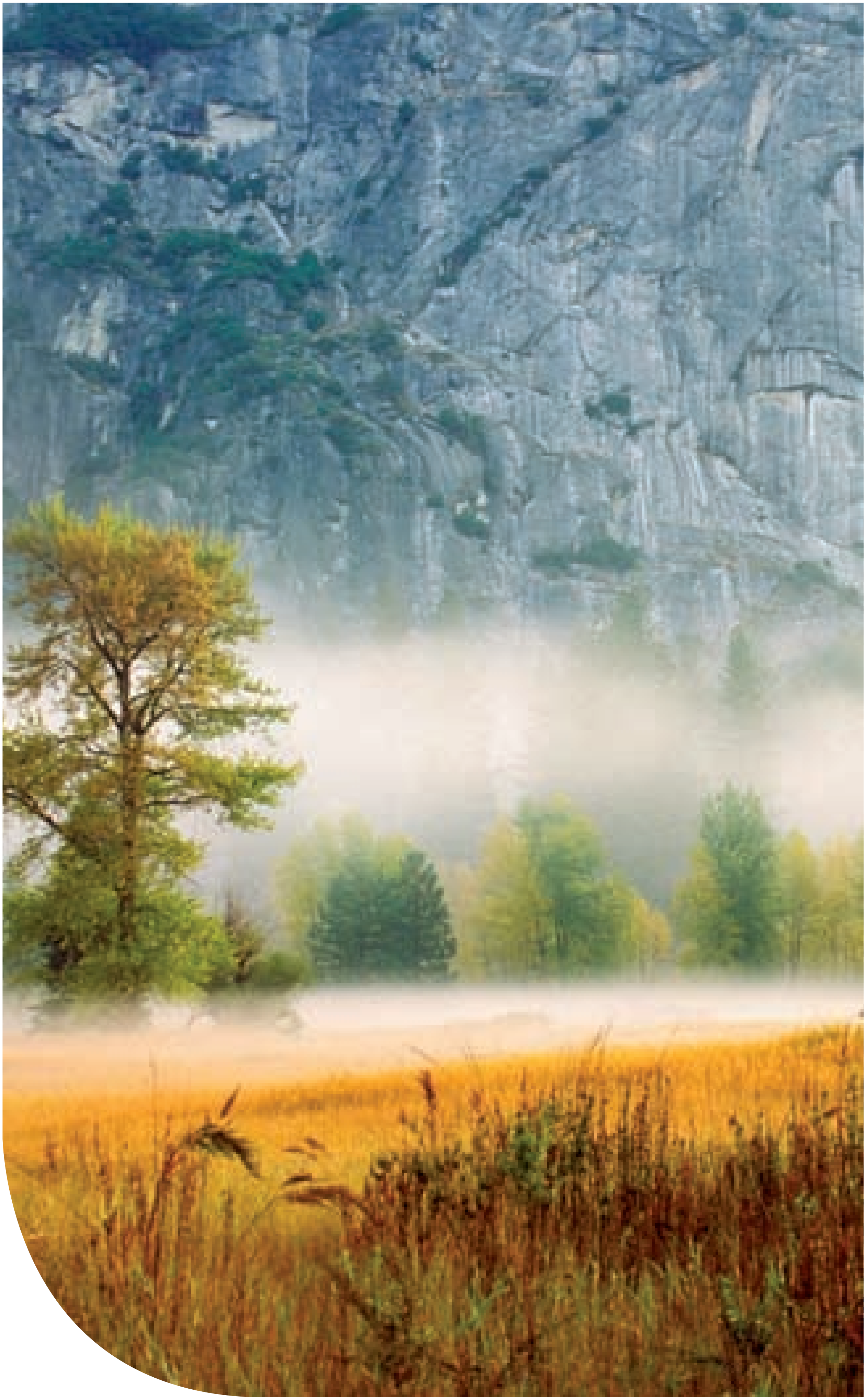

ISSUE BRIEF 7

COMPETITIVENESS IMPACTS OF CARBON DIOXIDE PRICING POLICIES ON MANUFACTURING

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SUMMARY

In the debate over the design of mandatory federal climate change policy, the potential for adverse impacts on the competitiveness of U.S. industry, on domestic jobs, and on the nation's balance of trade consistently emerges as a key concern. This issue brief explores how production across individual manufacturing industries could be affected by a unilateral policy that establishes a price on carbon dioxide (CO_2) emissions. (Issue Brief #8 examines possible policy responses to address these impacts.) Our review of existing analyses and new research[1] on the topic of climate policy and U.S. competitiveness yields a number of observations:

- The impact of a CO_2 price on the competitiveness of different industries is fundamentally tied to the energy (and more specifically, carbon) intensity of those industries, and the degree to which firms can pass costs on to the consumers of their products. The answer to the latter question hinges on the extent to which consumers can substitute other, lower-carbon products and/or turn to imports.

- Industry-level studies of competitiveness tend to focus on the energy-price impacts of a specific CO_2 policy. They typically do not consider what level of carbon price would be required to meet a particular emissions-reduction target or how overall program stringency is coupled with decisions about offsets and/or a safety valve. Studies of competitiveness impacts typically also ignore "general equilibrium" effects, such as the possibility that shifting from coal to natural gas for power generation could drive up natural gas prices and have additional effects on the competitiveness of natural gas users.

- Energy costs in most manufacturing industries (broadly defined at the two-digit classification level) are less than 2 percent of total costs. However, energy costs are more than 3 percent of total costs in a number of energy-intensive manufacturing industries such as refining, nonmetal mineral products, primary metals, and paper and printing. For these more energy-intensive industries, total production costs rise by roughly 1 percent to 2.5 percent for each $10 increment in the per-ton price associated with CO_2 emissions (with less being known about the impacts of larger CO_2 prices). Also, cost impacts can be considerably greater within more narrowly defined industrial categories.

- Recent case studies in the European Union (EU) found more substantial impacts in some industries when narrower industry classifications were used and process emissions were also considered. Specifically, a $10-per-ton CO_2 price led to a 6 percent increase in total costs for steel production using basic oxygen furnace (BOF) technology; for cement, production costs increased by 13 percent. With free allowance allocation and some ability to increase prices, however, researchers have

1 Results of this work are forthcoming in two RFF Discussion Papers, one by J. Aldy and W. Pizer, and another by Morgenstern, Ho, and Shih. This issue brief does not consider competitiveness impacts arising from the regulation of non-CO_2 gases; see Issue Brief #13 for some discussion.

found that adverse impacts on industry can be reduced substantially. Using simple demand models, one study found that output in most industries declined less than 1 percent—and by at most 2 percent in the most strongly affected industries—for a \$10-per-ton CO_2 price with 95 percent free allocation.

- More generally, cost increases can be translated into impacts on production, profitability, and employment using either an explicit model of domestic demand and international trade behavior, or empirical evidence from past cost increases.

- Using an economic model of U.S. industrial production, demand, and international trade, Morgenstern et al. generally find adverse effects of less than 1 percent when estimating the reduction in industrial production due to a \$10-per-ton CO_2 charge. The exceptions are motor vehicle manufacturing (1.0 percent), chemicals and plastics (1.0 percent), and primary metals (1.5 percent). These estimates represent near-term effects—that is, impacts over the first several years after a carbon price is introduced—before producers and users begin adjusting technology and operations to the new CO_2-policy regime. Longer-term effects could be larger or smaller.

- Using an empirical analysis of historical data on energy prices and industry output across five countries, Aldy and Pizer find somewhat larger impacts. While a \$10-per-ton CO_2 charge is estimated to reduce industrial production by less than 1 percent in most cases—consistent with the results of the Morgenstern et al. study—considerably larger effects are found in some industries, notably non-ferrous metals (3.0 percent), iron and steel (6.0 percent), fabricated metals (1.8 percent), and machinery (3.9 percent).

- Impacts on domestic industries will generally be lower if it is assumed that key trading partners also implement comparable CO_2 prices or that border tax adjustments or other import regulations are used to address the CO_2 content of imported (and exported) goods. Analysis by Aldy and Pizer suggests that such assumptions reduce the estimated impact on domestic production among energy-intensive manufacturing industries by perhaps 50 percent.

- Various current proposals for a mandatory U.S. cap-and-trade program to limit greenhouse gas (GHG) emissions would give free allowances to different industries to help address economic burdens from a CO2 pricing policy.

- Calculations based on results from Morgenstern et al. suggest that for most industries where energy is more than 1 percent of total costs, giving away free allowances equal to around 15 percent of a firm's emissions from fossil-fuel and electricity use would be sufficient to address adverse impacts on shareholder value. This number varies widely, however, across different industries. As with earlier calculations, narrower industry classifications can produce much higher estimates of the free allocation necessary to address lost shareholder value.

Introduction

As the United States considers mandatory policies to address climate change, an important consideration is the potential for such policies to cause a significant decline in some domestic industries, along with a corresponding increase in imports and/or production elsewhere in the world. The potential for such impacts gives rise to at least two kinds of concerns: first, the risk of damage to the domestic economy and second, the risk that environmental benefits will be negated or offset to a significant extent if the result of the policy is to shift emissions-intensive production activities to unregulated regions of the world. These impacts are frequently referred to as competitiveness effects, or effects on U.S. competitiveness.

The impact of a CO_2 price on domestic industries is fundamentally tied to the energy (and, more specifically, the carbon) intensity of those industries, the degree to which they can pass costs on to the consumers of their products (often other industries), and the resulting effect on U.S. production. The latter question—that is, the likely impact on U.S. production—hinges on two factors: first, the extent to which domestic products face competition from imports and second, consumers' ability to substitute other, less carbon-intensive alternatives for a given product. The first of these factors relates directly to the environmental risk noted above: because climate change is driven by global emissions of GHGs, the benefits of a domestic policy could be substantially eroded if an increase in U.S. production costs caused the manufacture of emissions-intensive goods to shift to nations that do not adopt GHG policies, or that have substantially weaker policies.

The scale of these potential impacts is unprecedented in the history of environmental regulation, as is the range of industries that would be affected by a mandatory domestic climate policy. Quantifying potential impacts is also complex. By contrast, the debate leading up to the 1990 Clean Air Act Amendments was informed by extensive governmentand industry-sponsored analyses of the likely effects of a cap-and-trade program for sulfur dioxide emissions on the electric power sector. These analyses were greatly simplified by the fact that the policy under consideration targeted a largely regulated industry that faced almost no international competition. A pricing policy for GHG emissions would not only have much more significant direct impacts on coal and other domestic energy industries, it could adversely affect the competitiveness of a number of large energy-intensive, import-sensitive industries. Unfortunately, information concerning industry-level impacts associated with new carbon mitigation policies is quite limited.

This issue brief reviews two recent, detailed analyses of competitiveness effects on European manufacturing industries using case studies of key sectors, and presents some early results from two research projects underway at RFF that explore the potential impacts of a CO_2 price on U.S. manufacturing industries.[2] All of these analyses also consider how permit allocation schemes could affect net industry costs. Throughout the discussion that follows, we assume that the GHG policy is implemented in a single country or bloc of nations (the EU or the United States) and not on a global basis. Global implementation and/or the use of a border tax adjustment or similar policy would reduce the competitiveness effects of a national-level policy, a point to which we return at the end of this issue brief.

Importantly, the results presented here depend, in part, on the breadth of the industry classifications considered and, for some industries, on whether or not process CO_2 emissions are included. The EU studies discussed in this issue brief tend to focus on narrower industrial categories that are more energy-intensive than is typical for the broader industrial classification under which they fall. These studies also include process emissions. In contrast, both U.S. studies focus exclusively on combustion-related emissions and use somewhat broader industrial categories. Each of these features tends to reduce the magnitude of predicted competitiveness impacts. On the other hand, one of the U.S. studies includes emissions associated with intermediate inputs, which would tend to have the opposite effect of increasing the magnitude of predicted impacts. All the analyses reviewed here focus on industry averages. Actual impacts on individual firms—as well as within more narrowly defined sectors—could differ significantly from the industry-wide average. Finally, the emphasis in this issue brief is on summarizing the results of several different analyses; detailed methodological explanations will be available in the full studies. The question of what policy mechanisms might be available to address adverse competitiveness effects, meanwhile, is taken up in a companion issue brief (Issue Brief #8).

Recent EU Studies

Two recent studies have estimated the competitiveness impacts of the EU Emissions Trading Scheme (EU-ETS). One study was conducted by McKinsey & Company and Ecofys (hereafter, McKinsey) for the European Commission; the second was conducted by Reinaud for the International Energy Agency (IEA).[3] Both studies adopt a relatively straightforward framework for computing impacts, starting with a calculation of the cost increases that would arise from a particular CO_2 charge. The calculation includes emissions-related cost increases from the consumption of fossil energy and from process emissions, as well as the indirect cost of higher electricity prices.[4] The EU studies also consider the extent to which free permit allocation, based on direct emissions only, could mitigate estimated cost impacts.[5] While both studies focus on representative sub-sectors within particular energy-intensive industries, they also differ in certain respects. The more recent McKinsey study considers a carbon price of \$20 per ton CO_2, while the IEA scenario considers a price of \$10 per ton CO_2. Importantly, all of the studies discussed here, including the EU studies, take a specific CO_2 price as a given. That is, none of the studies attempts to address the question of what price would be required to achieve a particular emissions-reduction target, nor do any of the studies examine the cost impacts of other policy design choices, such as whether an offsets program or price-cap mechanism (safety valve) is included.[6] In addition, these studies ignore the possibility that fuel switching from coal to natural gas in the power sector could drive up natural gas prices, creating additional competitiveness concerns for industries that use natural gas.

The McKinsey study considers a 95 percent free allocation coupled with explicit assumptions about how much of any production-cost increase associated with a carbon price will pass through to higher product prices in different

2 The effect of including other greenhouse gases in any new regulatory scheme is not considered in these analyses; see Issue Brief #14.

3 McKinsey & Company and Ecofys (2006). EU ETS Review: Report on International Competitiveness; Reinaud, J. (2005) "Industrial Competitiveness Under the European Union Emissions Trading Scheme." International Energy Agency.

4 Both studies assume the power generation industry passes on the full opportunity cost of carbon allowances. To calculate costs associated with electricity consumption, the McKinsey study assumes 0.41 tons of CO_2 emissions per megawatt-hour (MWh); the Reinaud study uses the 2001 average CO_2 intensity of grid-supplied electricity. Neither study considers how facilities might respond to a carbon price by *reducing* direct emissions and/or electricity consumption, thereby lessening the cost impacts of the carbon policy.

5 While a free allocation clearly benefits shareholders, the question of whether a free allocation based on historic emissions would offset the production-cost increases that are relevant for competitiveness concerns (in terms of changing prices, production, and employment) remains open. Rules that rescind allocations if a plant closes would encourage facilities to use free allowances to offset costs; rules that allow facility owners to keep free allowances when a plant closes would not.

6 The question of how different targets translate to CO_2 prices is discussed in Issue Brief #3.

manufacturing industries. McKinsey bases these assumptions on the published literature and its own industry expertise. However, this analysis only goes so far as to calculate net cost impacts—it does not report predicted effects on output. In contrast, the Reinaud analysis considers both 90 and 98 percent free allocation, calculates the net effect on prices, and then applies demand elasticities from the literature to estimate changes in output. That is, McKinsey focuses on changes in net costs while Reinaud attempts to trace cost impacts through to effects on output, as the U.S. studies discussed later in this issue brief also do. Key results from the two European studies are displayed in Table 1, where we have interpolated the Reinaud results to match the 95 percent free allocation in the McKinsey study and have scaled both sets of results to match the \$10-per-ton CO_2 price used in the U.S. analyses discussed below.[7]

The results shown in columns 1 and 4 of Table 1 suggest that initial cost impacts, before adjustment for free allowance allocation or cost pass-through, vary widely across industry sub-sectors. This variation reflects differences in energy intensity and, particularly in the case of cement, differences in process emissions. Both the McKinsey and the Reinaud/IEA studies estimate the largest initial cost impacts in BOF steel, aluminum, and cement, with relatively smaller impacts in electric arc furnace (EAF) steel. McKinsey also finds relatively large initial impacts in the petroleum industry (not included in the study done for the IEA), while Reinaud finds relatively large initial impacts in newsprint (not studied by McKinsey).

Not surprisingly, net cost burdens fall significantly if industries are given a free allocation of allowances equivalent to 95 percent of their direct emissions, as shown in columns 2 and 5 of Table 1. The net cost burden after free allocation for BOF steel and cement, for example, falls by roughly 85–90 percent, an amount that reflects the substantial primary fuel consumption and only modest use of electricity that characterizes these industries. In contrast, electricity-intensive industries with significant indirect emissions from electricity use, like EAF steel, see a smaller decline (of roughly 10 percent) in the net cost burden under a 95 percent free allocation based only on direct emissions. This is because the EU ETS allocation scheme does not address cost increases arising from higher electricity prices (where higher electricity prices reflect the indirect emissions associated with power generation). Similarly, aluminum producers do not gain from free permit allocation under the EU ETS rules because of their limited direct emissions, despite the fact that this industry experiences large cost increases due to its heavy reliance on purchased electricity. Other industries with a mix of direct and indirect emissions—such as certain segments of the pulp and paper industry—fall in between.

The European studies differ most significantly in terms of how far they take the analysis. The McKinsey study develops explicit assumptions about cost pass-through for each industry—that is, how much of a given production-cost increase will show up in higher product prices. These assumptions, which are based on the published literature and on the authors' own expertise, are shown in parentheses in column 3 of Table 1. Estimated price impacts are based on the threshold change in revenue needed to keep a facility open, assuming no change in demand for the product (or facility output) in response to higher prices. Importantly, the analysis also assumes that firms will attempt to pass through all cost increases associated with the climate policy, regardless of free allocation. The Reinaud/IEA study instead applies demand elasticities—that is, it assumes that industrywide prices will rise to reflect the increase in costs but that demand and production will fall somewhat as a result (generally by 2 percent or less).

Assuming cost pass-through of 6 percent, the McKinsey study finds that the net impact on BOF steel, after a 95 percent free allocation, drops to 0.6 percent, as shown in column 3. For cement producers, with an assumed cost pass-through rate that varies from 0 to 15 percent (depending on location), estimated impacts after a 95 percent free allocation range from a net cost of 1.4 percent to a net *gain* of 0.6 percent.[8] For the highly competitive aluminum industry, the McKinsey study assumes zero ability to pass through higher electricity costs. As a result (and because the free allocation is based on direct emissions only), this industry experiences the largest competitive effects, as displayed in Table 1. By contrast, for petroleum refining—where McKinsey assumes a cost pass-through rate of 25–75 percent—the results suggest a net *gain* of 0.9–4.5 percent.

New RFF Studies

Two new analyses of U.S. manufacturing, one by Morgenstern, Ho, and Shih and the other by Aldy and Pizer, are nearing completion. Morgenstern, Ho, and Shih use a simulation model of the U.S. economy, including trade flows and an international sector, to estimate the domestic, industry-level

7 Studies were scaled to \$10/tCO_2 by assuming linear cost effects and using an exchange rate of C1 = \$1.39.

8 The analysis assumes that plants located near the coast cannot pass along higher costs because of competition from imports. By comparison, inland facilities that face less competition are assumed to have some ability to raise prices in response to increased costs.

Table 1 Estimated cost impacts under the EU ETS for various industries (as % of total production costs)

	McKinsey ($10/$tCO_2$)			Reinaud/IEA ($10/tCO2)		
	1	2	3	4	5	6
Industry	Cost increase (%)	Net of free allowances (%)	Net of allowances and cost pass-through* (%)	Cost increase (%)	Net of free allowances (%)	Demand reduction^ (%)
BOF Steel	6.2	1.0	0.6 (6%)	5.89	0.63	0.79 (-1.56)
EAF Steel	1.0	0.9	0.2 (66%)	1.65	0.63	0.36 (-1.56)
Cement	13.1	1.4	-0.6 to 1.4 (0% to 15%)	14.47	1.77	0.29 (-0.27)
Primary Aluminum	4.1	4.1	4.1 (0%)	2.70**	2.70**	2.09** (-0.86)
Secondary Aluminum	0.2	0.2	0.2 (0%)			
Newsprint				3.62	0.95	1.44 (-1.88)
Chemical Pulp	0.4	0.2	0.0 (50%)			
Paper from Chemical Pulp	0.8	0.4	0.3 to 0.4 (0% to 20%)			
Chemical Pulp/Paper	0.9	0.4	0.2 to 0.4 (0% to 20%)			
Mechanical Pulp/Paper	2.0	1.5	1.1 to 1.5 (0% to 20%)			
Thermo-Mechanical Pulp/Paper	2.7	2.2	1.7 to 2.2 (0% to 20%)			
Recovered Pulp/Paper	1.2	0.7	0.4 to 0.7 (0% to 20%)			
Average Process Petroleum Refining	7.4	0.9	-4.5 to -0.9 (25% to 75%)			

* Note: Estimated industry-level cost pass-through rates from the McKinsey study are shown in parentheses.
** Denotes figures for aggregate aluminum industry (primary and secondary).
^ Expected % reduction in demand assuming full pass-through of net costs (including free allocation). Assumed demand elasticities are shown in parentheses.

impacts of pricing CO_2 emissions. Aldy and Pizer conduct an econometric analysis of data on energy prices and industry performance across a number of countries and industries. As noted previously, the industrial categories considered by Morgenstern et al., based on available 2002 data,[9] are broader than those used in the EU studies, while Aldy and Pizer use categories somewhat similar to those of the EU analyses. Both of the U.S. studies focus exclusively on combustion emissions and ignore process emissions, although one of the U.S. studies (Morgenstern et al.) does include emissions associated with the purchase of domestically produced intermediate inputs. It should be noted that changes in production and energy use since 2002 are not captured by these studies.[10]

9 The calculations presented here are extrapolated from the Bureau of Economic Analysis *Annual Input-Output Table* for the 1997 benchmark. In addition, we used the Energy Information Administration's *Manufacturing Energy Consumption Survey* from 2002. We anticipate updating the calculations once the 2002 benchmark data become available.

10 As the climate policy debate has intensified in recent years, some industries may have already begun to adjust production in anticipation of future carbon regulation. For example, in the steel industry there is anecdotal evidence that some of the most carbon-intensive parts of the production process may have already moved off-shore and that more semi-finished steel is imported now than previously.

Results from the Morgenstern, Ho, and Shih Analysis

The Morgenstern, Ho, and Shih study focuses on plant managers' near-term options for responding to a CO_2 policy that raises the cost of energy (including electricity) as well as that of other intermediate goods. For example, a chemical plant that is suddenly faced with higher energy costs cannot immediately and costlessly convert to more energy-efficient methods. If plant owners leave output prices unchanged, the higher input costs will lower profits. If they instead raise prices to cover higher input costs, sales can be expected to decline. The extent of this decline would depend on the behavior of other chemical plants, other industries, and other sources of product demand. To capture some of these complexities, this analysis considers two different time horizons, immediate and near term.

In the immediate analysis, firms are assumed to have no opportunities at all to respond to higher energy (carbon) prices. That is, firms cannot raise the prices they charge for their outputs, alter the technologies used to produce those outputs, or make other process adjustments, such as substituting cheaper (lower-carbon) alternatives for now more expensive carbon-intensive inputs. Because product or output prices stay the same, the analysis assumes that customers also do not make any immediate adjustments in demand and continue to buy the product under consideration in the same quantities. These assumptions correspond to the assumptions used to estimate "cost increases" in the EU studies (that is, columns 1 and 4 of Table 1), except that the Morgenstern et al. analysis also considers the indirect effects of higher prices for all intermediate goods under a CO_2 pricing policy, not just electricity; and excludes process emissions.

Beyond the immediate time horizon, we would expect that when costs rise across an entire industry, product prices will rise in that industry. This increase in prices would at first increase revenues and thus offset the initial impact of higher costs, but eventually it would also lead to a decline in sales, employment, and profits as customers switch to substitute goods or overseas suppliers whose prices do not reflect a charge for CO_2 emissions.[11] At the same time—that is, within this near-term horizon—industry's ability to adjust the technologies it uses or to substitute cheaper (lower-carbon) inputs in the production process is constrained. Higher product prices mean increased profits per unit sold, but as demand falls, fewer units are sold and revenues and profits may begin to decline.

Over the longer term, firms are likely to substitute some inputs for others—for example, replacing steel with plastic—and generally find ways to save energy and reduce carbon-related costs. The ability to switch to less carbon-intensive inputs and technologies, in turn, ameliorates price and demand effects relative to expected effects in the immediate and near term. The larger economy is also adjusting and customers can be expected to begin altering their purchase behavior in response to new price signals. For example, cement producers may have more options for improving energy efficiency and reducing costs over the long run than they do in the short run. Thus, the long-term impact of a carbon pricing policy on any particular industry reflects a number of competing changes, and may be larger or smaller in net than it is over immediate and near-term horizons. Unfortunately, the results of RFF's longer-term modeling analyses are not yet complete.

To the extent that preliminary model results are available, they indicate that the impact of a carbon charge is most obviously linked to patterns of energy use in particular industries. Table 2 presents estimates of energy costs as a share of total costs. Column 1 displays electricity costs as a share of total costs, while column 2 displays the sum of costs associated with electricity use and direct combustion of fossil fuels. Note that crude oil used as a feedstock in the refining sector is not counted as an energy cost. Similarly, other non-fuel uses of oil and chemical products are also excluded. Even with this feedstock exclusion, however, petroleum refining is still the sector with the highest energy cost (16.4 percent). Other sectors with high energy costs relative to total cost are primary metals (4.7 percent); nonmetallic mineral products, such as cement (3.7 percent); and paper (3.4 percent). At the low end of estimated cost, there are motor vehicles (0.7 percent) and electrical equipment (0.9 percent).

Cost estimates for aggregate industry sectors hide considerable intra-sector variation. For example, estimated energy costs for the chemicals and plastics industry, when viewed at the aggregate level, amount to 2.9 percent of total production costs. However, based on more disaggregated data available for 1997, the range is much wider across specific subcategories within this sector: from 0.6 percent to 34 percent. Based on the earlier data, five of the more narrowly defined industries that fall under the heading of chemicals and plastics have energy cost shares in excess of 10 percent, while three have shares less than 1 percent.[12] Unfortunately,

11 In response to lower demand, domestic producers will also buy fewer intermediate inputs; however, we do not focus on that effect in this analysis.

12 The 6-digit data are available from the 1997 benchmark input-output table. In computing the 6-digit combustion shares we assume that the combustion to feedstock ratios across all 6-digit industries is equal to the average ratio for the whole 2-digit industry. It is possible that some of the variation in energy cost share is masking differences in feedstock use.

detailed data on energy expenditures are not yet available for 2002, and there are no data on actual energy use at the level of detail necessary to separate feedstock use from combustion use. Nonetheless, it would be useful to add more detailed data to the Morgenstern et al. analysis in the future to develop a better sense of the range of output effects and net costs, taking into account compensation in the form of allowance allocation.

One major concern associated with pricing CO_2 emissions is that this policy will cause consumers to substitute imports for domestic products. While the potential for increased import substitution is not necessarily linked to current import levels, Table 2 presents information on the current import share of U.S. consumption in column 3 to give an indication of the potential vulnerability of different industries to overseas competition.[13] Apparel has the highest import share, and also has high electricity costs as a share of total costs. Electrical equipment and motor vehicles have relatively high import shares but they are not as energy-intensive. Among the most energy-intensive manufacturing sectors, the primary metals sector has the highest import share at 21 percent, followed by chemicals (20 percent) and nonmetallic mineral products (15 percent).

Over a near-term time horizon, Morgenstern et al. consider the immediate impact of a carbon charge where producers do not adjust prices or technologies—they just pay for the CO_2 content of the energy and intermediate goods they consume. The effect of a \$10-per-ton CO_2 charge on overall production costs is given in the last three columns of Table 2, broken down by effects from the use of direct fuel (column 4), electricity (column 5), and intermediate goods (column 6).[14] Columns 7 and 8 sum these effects to show the total impact due to costs from energy use only, as well as from energy use associated with the consumption of intermediate goods. The largest total cost impacts are in the refining sector (2.3 percent), primary metals (1.5 percent), nonmetallic minerals (1.0 percent), paper and printing (0.9 percent), textiles (0.6 percent), and chemicals and plastics (0.6 percent). Over an immediate time horizon, output prices are regarded as fixed and there is assumed to be no demand response: that is, customers continue to buy the same quantities of goods (output) as long as prices don't change. As a result, the expected decline in profits simply equals the expected increase in input costs. These effects are generally lower than the results reported in the EU studies, as becomes evident from a comparison to columns 1 and 4 of Table 1. This is due primarily to the fact that the EU studies use narrower classifications to focus on specific industries with high energy use, and, in the case of cement, include process emissions.

Beyond the immediate time horizon, there will be upward pressure on prices to recover the higher costs shown in column 8 of Table 2. The impact of higher prices on sales is estimated by simulating the response for each industry using a model of the U.S. economy.[15] This model allows buyers to choose among the outputs from different industries and to choose between domestic suppliers and importers. Buyers include other firms, households, and exports. Importantly, at this stage of the analysis the industry being scrutinized is itself not allowed to choose different combinations of production inputs. Using this model and assuming that the industry-wide increase in product prices is equal to the increase in costs reported in Table 2, the expected change in output for different industries under a \$10-per-ton charge on CO_2 emissions is shown in column 1 of Table 3.[16]

In all sectors, the decline in sales depends on the elasticity of demand. Primary metals see the largest drop (1.5 percent) followed by chemicals and plastics and motor vehicles (both 1 percent). Fabricated metals and wood and furniture are estimated to experience the smallest demand reductions. Petroleum products likewise experience a relatively small decline (0.4 percent). Over time, however, as evidenced by the oil shocks of the 1970s, impacts on the petroleum sector could increase significantly. The results for this U.S.-based analysis can be compared to the EU estimates in column 6 of Table 1, but it is important to note that the EU estimates include the benefits of a free allocation to producers, while the estimates for U.S. industries in Table 3 do not.

Results from the Aldy and Pizer Analysis

Aldy and Pizer take an entirely different approach in attempting to quantify the effect of a CO_2 charge on the competitiveness of U.S. industries. They utilize the close relationship between carbon regulation and energy prices to study how policy-induced changes in the cost of fossil energy affect industry-level output, employment, and other commonly used metrics of competitiveness. The analysis is

13 Energy cost share is defined as the value of purchases of electricity and fuel divided by net industry output. The official data from the BEA or BLS is gross industry output which includes transactions between establishments within the same industry. These intra-industry transactions are excluded from our measure of output.

14 An important distinction between this competitive analysis and the EU studies is the consideration of how CO_2 pricing will raise the price of intermediate goods, not just fuel and electricity. For energy-intensive goods, this distinction is relatively minor as the direct effect through energy dominates; for less energy-intensive goods, such as motor vehicles, however, the indirect effect through intermediate goods—such as steel—dominates.

15 Adkins, Liwayway and Richard Garbaccio (2007) "Coordinating Global Trade and Environmental Policy: The Role of Pre-Existing Distortions," mimeo, National Center for Environmental Economics, US EPA; see forthcoming discussion paper for further details.

16 The effect on petroleum refining also assume that refined products—both domestic production and imports—face a similar \$10-per-ton CO_2 charge.

strictly econometric: it relies on historical data to examine the competitiveness impacts of past electricity price changes over the short to medium timeframe, controlling for a range of other relevant factors.[17] Electricity prices are used as a proxy for energy prices because of the lack of consistently available fuel price data in other countries.[18] The analysis focuses on industry behavior in Australia, Canada, New Zealand, the United Kingdom, and the United States over the period 1978–2000. Aldy and Pizer focus on industry responses in these countries because they have similar flexibility in their labor markets; a wider data set of 26 countries is also available.

Their analysis provides statistical estimates of the average effect of electricity prices on output in manufacturing industries, controlling for the subject nation's real GDP, an index of foreign electricity prices, the real exchange rate, any other fixed differences (i.e., differences that are unchanging over time), as well as simple differences in secular trends (that is, different growth rates) across countries.[19] Similar to the analysis by Morgenstern et al., Aldy and Pizer then use their effect estimates to explore how a given CO_2 price would increase energy prices and cause output to decline in particular industries. The key results are displayed in column 2 of Table 3.

Compared to the Morgenstern et al. estimates in column 1, the output effects estimated by Aldy and Pizer are two to six times higher. Comparing the Aldy and Pizer estimates to the EU case study results shown in column 6 of Table 1 (and adjusting for the effects of free allowance allocation to the steel industry in the latter analysis), the output effects estimated by Aldy and Pizer are slightly low for steel and high for aluminum (non-ferrous metals). These differences may arise because the data sources and analysis techniques are different, because the European industries analyzed simply behave differently than their U.S. counterparts, or because the policy experiment is different. Industries in some of the smaller countries in the Aldy and Pizer analysis (Australia, New Zealand, and Canada) may be more import sensitive than industries in the United States, the United Kingdom, or the EU. Also, because Aldy and Pizer use historical variation in national energy (electricity) prices to identify effects on industrial output, they are implicitly considering the impact of many other price changes that may go along with energy/electricity price changes (this is akin to the effort by Morgenstern et al. to include effects from rising prices for intermediate goods).

In any case, the range of estimated impacts shown in column 6 of Table 1 and in both columns of Table 3 is informative in two respects. First these estimates provide a sense of the absolute magnitude of likely impacts. Second, even if it remains difficult to pin down the absolute magnitude of output effects, these estimates provide information about relative impacts across different industries and can help to identify sectors that are especially vulnerable to adverse competitiveness impacts under a carbon pricing policy.

Allowance Allocation

While the EU-ETS provides for a near-100 percent free allocation, various domestic policy proposals currently under consideration in the United States are less specific on this issue. One option is to give energy-intensive industries an allocation of free allowances roughly equal to their carbon emissions—where that quantity reflects either direct fuel-related emissions only or all emissions, including indirect emissions arising from electricity use. Alternatively, allocation methodologies could be devised around some notion of compensating firms for lost shareholder value as a result of the climate policy. To get a sense of the difference between these approaches, the results from Morgenstern et al. can be used to quantify the relationship between carbon emissions and the potential for lost shareholder value. If policymakers are concerned about immediate cost impacts under a CO_2 policy, it is instructive to compare the estimates reported in column 8 of Table 2 to the value of CO_2 allowances associated with a 100 percent free allocation (where this value is obtained by simply multiplying each industry's carbon emissions by the \$10-per-ton CO_2 price used in the analysis). If the concern is to address impacts over a somewhat longer time horizon (several years), one could compare the additional impact—positive or negative—associated with rising product prices and declining product demand and compare that to the same allowance value. This calculation is also instructive for understanding more generally the magnitude of the impact a carbon price might have on industry profitability. Comparing effects on profitability to CO_2 allowance value, in turn, can help policymakers develop a sense of how many free allowances might be required to compensate firms in different industries for lost shareholder value.

17 The Aldy and Pizer research includes two data sets, one U.S. and one international. Here, we report only on the international results that provide industry-level detail.

18 By the end of the sample period, electricity represented 70 percent of total manufacturing energy costs in the United States and 88 percent of manufacturing industries reported that electricity accounted for the largest share of their energy costs. Further, electricity price changes are highly correlated with underlying fossil-fuel price changes.

19 Aldy and Pizer consider various specifications with employment, value added, and value of shipments as the predicted variable. Because of the difficulty of isolating output from the value of shipments, these results focus on the specification that uses employment as the predicted variable.

Table 2 Energy cost shares, import shares, and effect of a $10/ton carbon charge on costs

	1	2	3	4	5	6	7	8
	Energy share of total costs (%)		Import share of total use (%)	Effect of higher energy prices on unit costs (%)				
	Electricity share	All energy (excl. non-combustion)		Direct fuel combustion	Electricity use	Other intermediate inputs	Energy subtotal	All intermediate inputs
Food	0.91	1.85	8.2	0.13	0.09	0.34	0.22	0.56
Textile	1.90	2.95	27.8	0.17	0.36	0.10	0.53	0.63
Apparel	0.56	0.87	74.2	0.03	0.06	0.21	0.10	0.30
Wood & Furniture	0.93	1.45	22.5	0.17	0.13	0.05	0.30	0.35
Paper & Printing	1.49	3.44	11.9	0.85	0.25	0.00	1.10	1.11
Petroleum	0.79	16.37	11.2	2.38	0.12	0.00	2.49	2.50
Chemical & Plastics	1.46	2.78	26.7	0.34	0.28	0.01	0.62	0.45
Nonmetallic Mineral	1.55	3.71	16.3	0.76	0.30	0.01	1.06	1.07
Primary Metals	2.15	4.73	27.2	0.89	0.84	0.01	1.73	1.58
Fabricated Metals	1.09	1.76	13.6	0.06	0.13	0.34	0.19	0.53
Machinery	0.54	0.89	31.0	0.03	0.07	0.29	0.09	0.39
Computer & Electrical Equipment	0.67	0.89	51.1	0.03	0.09	0.16	0.12	0.28
Motor Vehicles	0.42	0.70	43.3	0.04	0.07	0.31	0.10	0.42
Other Transportation Equipment	0.41	0.77	26.7	0.03	0.06	0.21	0.09	0.30
Misc. Manufacturing	0.53	0.78	39.2	0.02	0.05	0.25	0.07	0.32

Table 3 Effects on output of a $10/ton CO_2 charge (%)

	Output effect from Morgenstern et al. input-output estimates	Output effect from Aldy and Pizer time series study*
Food	-0.37	
Textile	-0.78	
Apparel	-0.78	
Wood & Furniture	-0.26	
Paper & Printing	-0.48	
Petroleum	-0.42	
Chemical & Plastics	-0.96	
Nonmetallic Mineral	-0.66	
Primary Metals	-1.54	-5.96 Iron and Steel -3.01 Nonferrous metals
Fabricated Metals	-0.27	-1.75
Machinery	-0.66	-3.92
Computer & Electrical Equip	-0.72	
Motor Vehicles	-1.01	
Other Transportation Equip	-0.73	
Miscellaneous Manufacturing	-0.53	

* Results are only reported for those industries where the authors have the most confidence in their approach (high energy-intensity without significant sales of co-generated electricity or use of fossil feedstocks). All results are statistically significant.

Table 4 shows what percentage of different industries' emissions would have to be covered by an allocation of free allowances to fully offset estimated losses in shareholder value under a mandatory policy that priced CO_2 at $10 per ton. Results are shown only for industries where energy costs account for more than 1 percent of total costs. Two estimates are reported in Table 4: one assumes that industries could only claim allowances for their direct CO_2 emissions; the second assumes that a free allocation would also reflect emissions associated with electricity use, in addition to direct emissions. Taking into account only direct emissions—the more common approach used in past allocation designs—the share of emissions needed to compensate firms for losses using free allowances ranges from a low of about 1 percent in the petroleum industry to a high of about 73 percent for chemicals and plastics.[20] On average, for the industries included in Table 4, a free allocation equivalent to approximately 20 percent of direct CO_2 emissions should be sufficient to compensate firms for adverse impacts under a $10-per-ton policy.

At first glance, some of the results presented in Table 4 seem counterintuitive. As a share of direct emissions, only a relatively small allocation of free allowances would be required to compensate the primary metals industry, for example, even though column 1 of Table 3 indicates that this industry suffers relatively large output losses. This is because the carbon intensity of the industry is also very high: thus, even though the adverse impacts of a carbon price are relatively high, they can be covered by a relatively small share of the free allowances the industry could claim under an allocation based on historic emissions. In contrast, the apparel industry also faces substantial output losses, but because it is less carbon intensive—that is, it has lower emissions per unit of output—this industry requires a larger free allocation, relative to its emissions, to be compensated for adverse impacts on shareholders. Similar cross-industry patterns emerge if direct and indirect emissions are considered as the basis for allocation—in that case, a free allocation corresponding to approximately 15 percent of total emissions (including emissions from electricity and direct fuel use) would be required, on average, to offset industry losses. The implication of these estimates is that giving out free allowances in excess of the emissions share indicated in Table 4—including a 100 percent free allocation—would more than compensate even energy-intensive industries, at least on average, and lead to overall gains in shareholder value.

Table 4 Share of allowances* needed to compensate energy-intensive industries** for losses under a $10-per-ton CO_2 pricing policy

	Share of CO_2 emissions from direct fuel use (%)	Share of CO_2 emissions from direct fuel and electricity use (%)
Food	43.7	25.4
Textile	30.7	9.7
Wood & Furniture	18.7	10.8
Paper & Printing	8.2	6.3
Petroleum	1.2	1.1
Chemical & Plastics	72.8	40.4
Nonmetallic Mineral	20.1	14.5
Primary Metals	17.8	9.2
Fabricated Metals	64.2	20.0

*Share of allowances is defined as share of each industry's initial emissions levels.
**Energy-intensive industries are defined as industries with energy costs greater than 1 percent of total costs.

Border Tax Adjustments

Our baseline assumption throughout has been that carbon policies are (or would be) adopted unilaterally by the EU or the United States. The resulting impacts on domestic industries would generally be lower—indeed, probably substantially lower—if key trading partners implement comparable CO_2 control policies or if border tax adjustments are introduced to address the CO_2 content of imported (and exported) goods.[21]

Aldy and Pizer attempt to estimate the potential gains from a border tax adjustment by including a measure of foreign energy prices in their statistical model. Including this measure allows them to ask how an increase in both domestic and foreign energy prices, driven by a CO_2 charge, would affect industry output. While the output effects of foreign prices are harder to measure than the effects of domestic prices, Aldy and Pizer find that impacts on domestic industries might be reduced by as much as half if policy action by the United States to limit CO_2 emissions were coupled either with comparable action by other trading partners or with policies to adjust import prices at the border. Similar questions will be explored as part of further analysis to be undertaken by Morgenstern et al.

20 For example, the EU ETS allocates allowances based on direct CO_2 emissions, which is why EAF steel and aluminum were not significantly advantaged by free allocation in Table 2.

21 Of course, the implementation details of a system of border taxes would matter a great deal—for example, whether the border tax adjustment only covered basic products such as steel, aluminum, and cement rather than also including automobiles, appliances, or other finished goods. These issues are discussed at greater length in Issue Brief #8.